IRRIGATION STRATEGY OF SERBIA

SUPPORTING THE DEVELOPMENT OF AN IRRIGATION STRATEGY FOR SERBIA

Brief 6: Irrigation in Serbia

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Terms of Reference

Prepare a brief and detailed presentation on the existing irrigated agriculture framework in the Republic of Serbia including a description of technologies in use off-farm and on-farm. The brief will include a detailed cost opportunity analysis of irrigation at the farm level. The brief will analyse available data and policies from the Ministry of Agriculture, Water Management Directorate, Statistical Office, Farm Accountancy Data Network (FADN) survey, Farm Register, and international sources such as FAOSTAT that are relevant to the assignment.

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1 IRRIGATION IN SERBIA

When it comes to irrigation, Serbia has a regionally unique asset in the Danube-Tisa-Danube canal system of Vojvodina. Begun in the 19th century as a shortcut for barges travelling along the Danube, the "DTD" system was quickly expanded with a network of secondary canals for drainage and flood protection. Irrigation was added later, mainly by pumping from the canals but also in some cases by using sub-surface drains to maintain a constant water level throughout the year. It is not much of an exaggeration to say that irrigation in Serbia can be divided into two parts: the DTD system and everything else.

In the Socialist period, around 15 % of Serbia's land was managed by cooperatives and large, socially owned "kombinats"[1], many of which developed their own irrigation systems. Those drawing water from the DTD system had contracts with the regional water management organisation *Vode Vojvodine*, but in Central Serbia they arranged their own supply from rivers, reservoirs and boreholes, without even a central register of irrigation systems.

One of the most fundamental divisions in irrigation is between "individual irrigation", where one farm is solely responsible for abstracting, distributing and applying its own irrigation water, and "multi-user irrigation", where one or more organisations are involved in abstracting the water and delivering it to many different users. Most of the attention in irrigation projects and policies is focussed on these multi-user systems, on issues such as modernising, rehabilitating and expanding the common infrastructure, establishing Water Users' Associations or other structures to manage the system, and setting tariffs that encourage efficient water use and raise sufficient funds to allow proper maintenance and operation of the common system.

For water supplied from the DTD canal, *Vode Vojvodine* was responsible for managing the common infrastructure, with practical implementation contracted out to a number of "Water Utility Companies". However, once water left the canal, and in the rest of the country where there were no canals, the socially-owned farms had sole responsibility for their own irrigation systems. Effectively, Serbia had many large individual irrigation systems and almost no multi-user systems.

In recent years, more attention has been given to creating new multi-user irrigation systems. A number of projects have been prepared and are in various stages of design and implementation, including several to be financed by the Abu Dhabi Fund. The team is working to compile a complete database of multi-user irrigation systems in Serbia and to show the current status of each. So far, the team has identified four systems as being fully operational, though this number is expected to grow as more data are received.

[1] "Agro-kombinats" were involved only in agriculture, whilst "agro-industrial kombinats" combined primary production with processing. The kombinats farmed state-owned land, whilst the land of cooperatives remained theoretically the property of its members. Kombinats and cooperatives together were known as the "social sector" of agriculture. In 2001, just before the beginning of privatisation, there were 570 kombinats with an average size of 1,100 ha and 540 cooperatives with an average of 250 ha each, together accounting for 15 % of total land and 15 % of arable land. However, the social sector was much larger in Vojvodina, where it managed 34 % of total land compared to 6 % in Central Serbia. Source: Republic Statistical Office (2002). *Statistical Yearbook of Serbia 2002*.

Multi-user irrigation systems currently functioning in Serbia

Mali Iđoš

This is a new irrigation canal linked to the DTD system and supplied through a pump station; the first section of canal has recently come into function, and it is planned to extend it several kilometres further. Users sign a contract with and pay to Vode Vojvodine but the farmers are responsible for getting the water from the canal to their fields.

The management and financial arrangements are essentially the same as for farmers taking irrigation water from the DTD two-way drainage system.

Negotinsksa nizija

This is a pressurised system currently covering 1,100 ha in Negotin municipality. Water is supplied by a pump station managed by the "Elixir" fertiliser company, under a deal agreed when the factory was privatised. Currently water is provided free of charge and so there are no contracts or fees.

The government of Serbia has recently agreed a loan with EBRD, under which this system will be modernised and expanded, and supplied by a new pump station not connected to the "Elixir" company. It is expected that the system will be managed by Negotin municipality but the management arrangements and fee structure have yet to be determined.

Resavska celina

This is a planned irrigation system in Svilajnac municipality, also being funded under the EBRD loan. It is not yet in function and, as at Negotin, detailed arrangements have yet to be agreed.

Striza Water Users' Association

This system in Central Serbia is structured as a Farmers' Association and run by its members.

This history of irrigation being run by individual farms means that Serbia has almost no experience in the technical, institutional and financial challenges of running multi-user irrigation systems. Serbia does not yet have a law on Water Users' Associations, there is no established approach for management of local systems, and the current regulation on water tariffs does not address the question of how these local systems should be funded.

On the positive side, Serbia has the opportunity to learn from experience elsewhere and to develop a modern, efficient and sustainable approach to managing and financing multi-user irrigation systems.

1.1 Development phases for farm and irrigation structures

Serbia's irrigated agriculture must be viewed in the context of the agricultural sector as a whole, which has been shaped by the processes of political and economic transition over the last 30 years.

During the Yugoslav period, much of Serbia's best arable land was managed by large "agro-kombinats", several of which carried out agro-processing along with primary production. Small private farms were encouraged to join agricultural cooperatives as a source of inputs and an outlet for their produce.

Serbia has a very large network of navigation and drainage canals in the Danube-Tisa-Danube (DTD) system in Vojvodina, with some of its rivers and canals also supporting irrigation. However, Serbia did not develop large irrigation canal systems like those in Albania or North Macedonia, and almost all

the substantial irrigation systems were developed by individual agro-kombinats to meet their own needs. The kombinats managed and operated these irrigation systems and there was no central irrigation agency like those found in many other countries. In most cases, small farms that wished to irrigate had to find their own sources of water from boreholes and local rivers, though there were occasional exceptions such as the Parmenac system near Čačak, which was built in the 1960s to provide gravity irrigation to many small plots. Other than these few local exceptions and the large DTD system, most irrigation in Serbia has always been "individual irrigation", in the sense that one farm managed the whole process from abstraction to irrigating the crop, with no institution directly involved.

The kombinat systems began to decline during the conflict, sanctions and economic turmoil of the 1990s, followed by a privatisation process in the new millennium. In some cases, private farms have become the managers of large areas of former kombinats and have been able to maintain or rehabilitate and modernise their original irrigation systems. In other cases, land has been returned to its former owners or their heirs, or occasionally leased out in smaller blocks. Generally, these smaller landowners have developed their own irrigation solutions, rather than trying to convert former kombinat infrastructure into local multi-user irrigation systems.

An important institutional consequence of this is that Serbia has not had the same need for "Irrigation Management Transfer" and the formation of Water Users' Associations that has played such a large part in the irrigation agenda of many other ex-socialist countries.

One statistical consequence is that most of the irrigated area is not managed by any official organisation and so is not covered by regular administrative reporting. The Statistical Office continues to publish an annual bulletin of irrigation by legal entities, which manage much of the former kombinat land, but this does not cover the much larger area irrigated by private households[2]. Data on the irrigation customers of Srbijavode and Vode Vojvodine also covers mainly legal entities and so leaves the same gap for the private small-farm sector.

Therefore, a comprehensive picture of irrigated agriculture is only provided by the occasional full census or large-scale farm structures survey.

Change in land areas by ownership

Figure 1 below shows the areas of land under social and private ownership in 1990, when social ownership reached its greatest extent, and in 2001, the last year before economic transition and the beginnings of privatisation:

- The *social* sector comprises company farms (mainly kombinats and institutions) and cooperatives, together with state-owned pastures and wetlands managed or leased out by the state.
- *Cultivated* land comprises arable fields and gardens, orchards, vineyards and meadows; *other* land comprises pastures and wetlands.

[2] As an example, the annual bulletin for 2018 reported 46,823 ha of irrigated land on legal entities, representing just 29 % of the 159,587 ha recorded in the Farm Structures Survey of the same year.

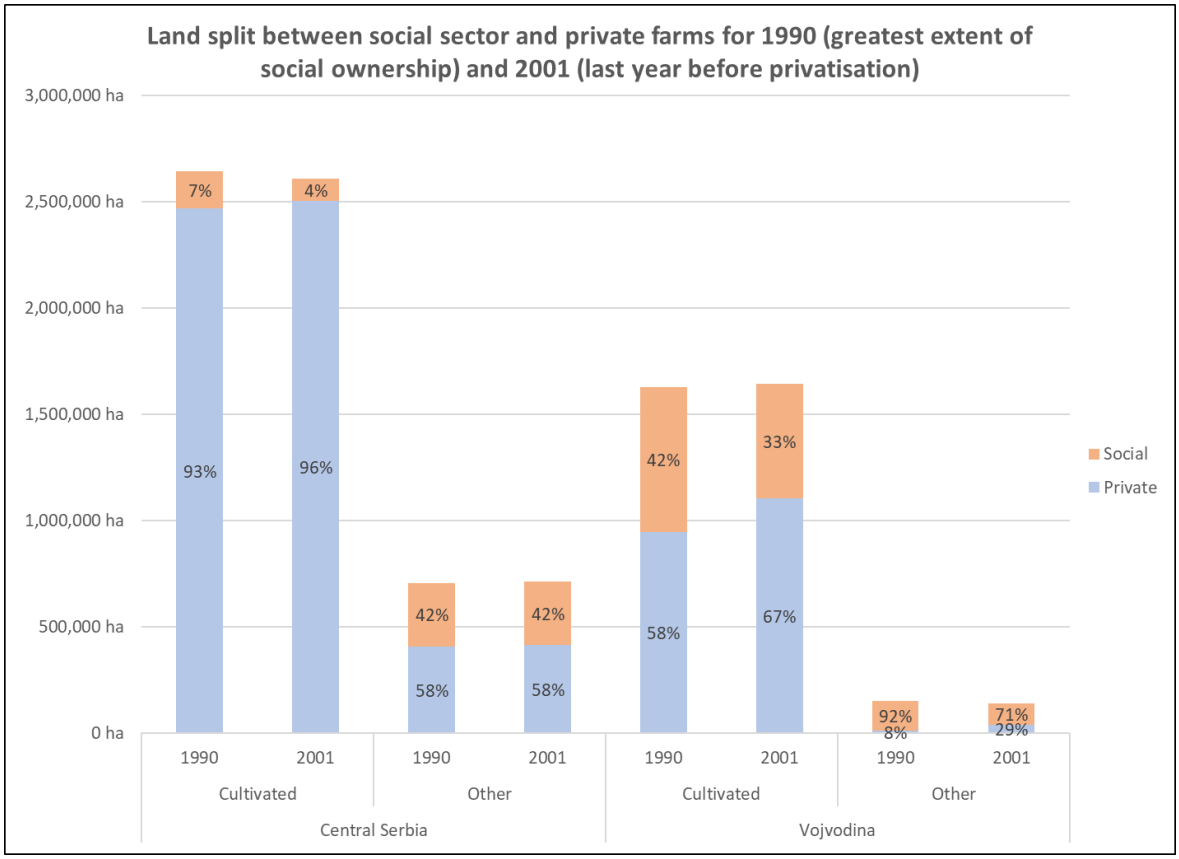


Figure 1. Land split between social & private ownership in 1990 & 2001; *Source: Republic of Serbia Statistical Office (1998), Agriculture of Serbia 1947-1996; Republic of Serbia Statistical Office (2002), Statistical Yearbook 2002.*

In Central Serbia most of the cultivated land stayed in private hands throughout the Yugoslav era, with a maximum of 7 % under social ownership in 1990, dropping to 4 % by 2001. However, 42 % of the pastures and wetlands were socially owned across this period.

Social ownership was a lot more significant in Vojvodina and accounted for 42 % of cultivated land in 1990, though this had already dropped to 33 % by 2001. The limited area of pastures was mainly under social ownership, which accounted for 92 % of pasture area in 1990 and had dropped to 71 % by 2001.

Hence, although Vojvodina has only one third of Serbia's land, in 2001 it accounted for 61 % of all socially-owned land and 83 % of all cultivated land under social ownership[3], where most of the large irrigation systems were constructed.

Public sector farms in 2001

In 2001, socially managed and state-owned land comprised three groups:

- ***Kombinats and institutions (62 % of state & social land)***
  - Most of this land was managed by agri-kombinats and agro-industrial kombinats, though some was farmed by educational establishments, research institutes, prisons, etc.
  - Land was owned by the state and the kombinats were granted a right to use it. Other assets, such as buildings, machinery and irrigation equipment, were owned by the kombinats, in the same way that other public companies owned their assets.

[3] All data exclude the Province of Serbia and Metohija, and percentages are of the totals for Central Serbia plus Vojvodina.

- Central Serbia had 312 public company farms with an average of 460 ha each, giving 144,000 ha in total.
- Vojvodina had 261 public company farms with an average of 1,940 ha each, four times the size of those in Central Serbia, giving 507,000 ha in total.

- ***Cooperatives (13 % of state & social land)***
  - Земљиште у задругама било је првенствено у власништву чланова задруге, али су у овој фази задруге почеле да функционишу слично као комбинати, па је директор задруге доносио већину одлука. У многим случајевима, задруге су блиско сарађивале са суседним комбинатима и њихово земљиште је практично припојено.
  - Land in cooperatives was nominally owned by the members, but by this stage they had come to operate quite similarly to kombinats, with the cooperate director making most of the decisions. In many cases, cooperatives worked closely with neighbouring kombinats and their land became effectively merged.
  - Central Serbia had 536 cooperatives with an average of 75 ha each, giving 40,000 ha in total.
  - Vojvodina had 187 cooperatives with an average size of 510 ha, nearly seven times the size of those in Central Serbia, giving 95,000 ha in total.
- ***Пашњаци и мочваре у државном власништву (25% државног и друштвеног земљишта) State-owned pastures and wetlands (25 % of state & social land)***
  - These covered two statistical categories of land: pastures and "Ponds, fish-ponds and reed tracts".
  - The number of separate parcels is not recorded, but Central Serbia had 220,000 ha of such land, whilst Vojvodina had 37,000 ha.

In terms of cultivated land, which is of greatest interest for irrigation, 82 % of the area under state and social ownership was managed by kombinats and other companies, 15 % by cooperatives and just 3 % under direct state management.

Privatisation and restitution

The last twenty years have seen processes of privatisation and restitution which, as in many countries of the region, have often been drawn-out and controversial.

Kombinats were offered for sale by the Privatisation Agency. In theory the buyers were only purchasing the buildings, machinery and equipment but would continue to enjoy the kombinats' right to use state-owned land. In practice, much of the land ended up registered as the property of the new owners, which were typically legal entities and often part of large holding companies. The smaller and medium-sized kombinats were normally privatised as one unit, whilst land from some of the very large kombinats, such as "PKB" (Poljoprivredni Kombinat Beograd) has been broken up and sold in stages.

Cooperatives were to return their land to its original owners through land restitution, but in many cases, it had become merged with that of neighbouring kombinats. Thus, the cooperatives had first to get their land back from the kombinats and then return it to their neighbours, a process which is still ongoing.

State-owned pastures remained in state ownership and are typically rented to farmers on multi-year leases.

Many of today's large private farms, particularly in Vojvodina, are former kombinats or cooperatives that went through privatisation. Their buyers became the full owners of any irrigation systems on the farm, including pipes, pump stations and irrigation machines. Given that there was little public investment during sanctions and economic crises of the 1990s, most of the original equipment would now be at least 30 years old, so most of the systems that are still functioning today have been extensively rehabilitated by the new owners.

1.2 Current forms of irrigation

Irrigation in Serbia can currently be divided into the following forms:

1. ***DTD canal system***, providing some farms with direct control of the water table via subsurface drains, and also providing the water source for…
2. …***private farms pumping water from the DTD canal system***, typically using irrigation systems that were built in the Yugoslav era but have since mostly been rehabilitated. These farms are mainly large former kombinats and coops, and usually operate as legal entities;
3. ***Ex-social sector farms elsewhere in Serbia***, also normally using rehabilitated systems;
4. ***Other private farms*** of all sizes throughout the country that have developed their own irrigation, most commonly without formal permits.

Groups 1 & 2, plus group 3 farms in Vojvodina, usually have supply contracts with Vode Vojvodine and are included in their database. Group 4, and group 3 farms in Central Serbia, are not systematically registered and so data on them comes mainly from censuses and surveys.

These groups and their water sources can be summarised as:

- DTD system:
  - Direct sub-surface irrigation
  - Pumping from canals
- Elsewhere:
  - Ex-social sector farms
    - Using surface water
    - Using groundwater
  - Other private farms
    - Using surface water
    - Using groundwater

1.3 Data sources

Quantitative data on irrigated agriculture can be drawn from both statistical and administrative sources.

1.3.1 Statistical data

There are three main statistical datasets of relevance:

- ***2012 Agricultural Census***. This aimed to cover all holdings in the country that met the minimum size criteria, including both legal entities and agricultural households. Respondents were asked for information about any irrigation taking place on their farm, whether from a public system or a private source, and regardless of whether they had a permit to abstract water. It may generally be regarded as an accurate an unbiased source, though it is now eight years out of date. Full results of this census have been published, and the project team was provided with access to a special analysis kindly prepared by the Statistical Office.
- ***2018 Farm Structures Survey***. This survey covered a representative sample of around 20 % of all holdings in the country, using a questionnaire that was largely similar to that of the 2012 Agricultural Census. Again, it covered all farm types and kinds of irrigation, and should be an unbiased data source. This survey has not yet been fully published, but the Statistical Office has prepared a special analysis to support work on the irrigation strategy.
- ***Annual Statistical Releases on irrigation***. These annual reports cover only legal entities, not private farms. They are therefore useful for tracking changes amongst corporate farms but cannot be taken as representing the entire irrigated sector. These releases are available on the website of the Statistical Office.

1.3.2 Administrative data

There are a few administrative datasets that give useful insights into some aspects of irrigated agriculture.

- ***Contracts with Public Water Management Companies***. Vode Vojvodine has contracts with farmers that receive irrigation and drainage services from the DTD system via the implementing "Water Utility Companies". This is thought to be a reasonably complete list of users, or at least, of the larger users, of the DTD system, though Vode Vojvodine believe that there are many unregistered water users in other parts of Vojvodina. In Central Serbia, rather few farmers have formal supply contracts with Srbijavode, so their database covers only a few large users. These datasets are useful for understanding the formal and paid provision of irrigation and drainage but cannot be taken as representing the entire sector.
- ***Data on rural development grant schemes***. The Ministry of Agriculture, Forestry and Water Management, and the Provincial Secretariat for Vojvodina, have for many years given grant support for investments in on-farm irrigation equipment. Clearly, these do not cover all farms but they may give some insights into the trends in irrigation development.

2 A STATISTICAL PICTURE OF IRRIGATED AGRICULTURE IN SERBIA

This chapter describes the current situation of irrigated agriculture in Serbia and how it got to here. It covers:

1. A short overview of agriculture in Serbia, both irrigated and rainfed, looking at the main agro-climatic zones, farm structures and the key socio-economic factors that influence whether and how farms use irrigation;
2. A detailed analysis of statistics on irrigated agriculture from 2012 and 2018.

2.1 Agriculture in Serbia

Irrigation and drainage take place within the wider context of agriculture, so this section gives a brief overview of agriculture in Serbia. The current situation is described on the basis of the 2018 Farm Structures Survey, and recent change is indicated by differences from the 2012 Agricultural Census.

2.1.1 Zones

Whilst agricultural statistics are available from national level right down to each of Serbia's 191 Municipalities, the most important geographical variations can be seen by dividing the country into three zones: Vojvodina, Central Serbia lowlands and Central Serbia uplands.

Vojvodina (1.5 m ha arable & permanent crops)

Vojvodina comprises almost all of Serbia's area north of the Sava and Danube rivers and has 1.6 m ha of agricultural land, 47 % of the national total excluding Kosovo. It is almost entirely flat and low-lying, with deep, rich Chernozem soils well suited to arable and vegetable production. Much of this area was originally marshland and is dependent on regular pumped drainage to keep it suitable for agriculture and to avoid flooding of roads, railways and urban areas.

The one exception is Fruška Gora, an area of 27,000 ha to the south-east of Novi Sad that rises to a height of 540 metres; 90 % of its area is forested but its agricultural land grows fruit and grapes as well as the usual range of arable and vegetable crops.

Vojvodina's artificial and natural drainage flows into the Danube, either directly or via the Sava and Tisa rivers, with the Danube-Tisa-Danube hydro-system draining 1 million of Vojvodina's 1.6 million hectares.

Vojvodina hosts almost 90 % of Serbia's very large farms (those over 50 ha) and 45 % of its large farms (10-50 ha). This is in part due to two aspects of history: firstly, that farm structures were generally larger in the Austro-Hungarian empire that included Vojvodina, compared to the Ottoman Empire that covered Central Serbia, and secondly that most of the big Socialist-era agri-kombinats were established in Vojvodina. Many of these structures have carried through to today's private farms, but even had history been different, the uniformity of Vojvodina and its suitability for mechanised arable production would have encouraged the formation of large fields and large farms.

Central Serbia lowlands (1.3 m ha arable & permanent crops)

Just over 90 % of Serbia's annual crops are grown at altitudes of less than 200 metres above sea level, and the land up to 500 metres includes almost all annual crops and 97 % of permanent crops

(fruit, grapes and nuts). Therefore, almost all of the crops that are or could be profitably irrigated lie in the lowland zone below 500 metres.

Geographically, lowland Central Serbia forms a rough V-shape, with the top of the V adjoining Vojvodina and the bottom of the V just south of Leskovac. There is also a significant area of isolated lowland around Negotin and east to the border with Bulgaria and Romania. The top of the V drains into the Sava to the west of Belgrade and into the Danube to its east, with a small area close to the Bosnian border draining into the Drina shortly before it joins the Sava. The centre of the V lies in the Morava basin, where the South Morava and West Morava join to form the Greater Morava, which flows north to discharge into the Danube near Smederovo. The Negotin plain drains east into the Danube.

Part of Belgrade region extends north of the Sava, and the Pannonian Plain, the ancient geographical feature that underlies Vojvodina and Hungary, extends south of the Sava around Maćva. In terms of topography, soils and farm structures, these two areas are more similar to Vojvodina than to the rest of Central Serbia.

Soil maps show a relatively consistent picture across this lowland area, in terms of the dominant particle size at each level in the profile. Compared to Vojvodina, the total available water capacity of soils is very similar, but most of the topsoil of lowland Central Serbia is loam whilst in Vojvodina clay-loam is more common.

Statistics are compiled by administrative area, not by altitude, and so show 1.8 m ha of Utilised Agricultural Area for Central Serbia as a whole. Of this, 1.3 m ha grow arable and permanent crops and lie almost entirely in lowland areas. The total agricultural area of lowland Serbia will be somewhat larger than this, since grass is also grown in the lowlands.

Central Serbia uplands (10,000 ha arable & permanent crops)

Land over 500 metres covers some 2.5 m ha of Central Serbia, 45 % of its total area. However, the large majority of this land is covered by grass or trees, plus some areas of water and bare rock, so there are only 10,000 ha of annual or permanent crops. This means that Central Serbia has little direct involvement with irrigation or drainage but plays a very important role in collecting the rain and snow that flow into the lowland rivers and contribute to aquifer recharge.

2.1.2 Farm size

Size plays a very important role in influencing what farmers grow and whether, how and what they irrigate. The analysis here uses six size groups:

- Small:
  - < 1 ha (very small)
  - 1-2 ha (small)
- Medium:
  - 2-5 ha (medium small)
  - 5-10 ha (medium large)
- Large:
  - 10-50 ha (large)
  - > 50 ha (very large)

The table on the next landscape page shows the number of farms, utilised agricultural area and average farm size by size group, for Central Serbia (lowland and upland together), for Vojvodina, and for all of Serbia excluding Kosovo; values for 2012 are shown in grey for comparison.

Variability of farms

The first thing to note is that Serbia's farms cover a very wide size range: it would take almost 340 very small farms to cover the same area as an average very large farm. Even excluding these two extremes, the average large farm is more than 12 times the size of the average small farm, and so is economically very different.

Size itself only gives part of the story: 1 ha of tomatoes would generate more revenue and require much more labour than 10 ha of wheat; this difference in intensity is a key factor in irrigated agriculture. Small farms tend to be more focussed on livestock and intensive crops, so the range of economic size is rather smaller than suggested by land area alone.

Size distribution by province

Very large farms (those over 50 ha) account for less than 1 % of all farms but 28 % of agricultural area. There are 5,200 of these farms, of which 4,200 are in Vojvodina. Of the 1,000 very large farms in Central Serbia, a few hundred are upland pasture farms, so 80-90 % of all very large crop farms lie in Vojvodina. Many of these are former agro-kombinats that have since been privatised, and some of these will have continued and renovated the irrigation systems originally built by the kombinats.

At the other end of the scale, 40 % of all farms are small or very small (up to 2 ha); these account for 6.4 % of total agricultural area but, as shown in section 2.2.3, a much larger share of intensive crops. These smaller farms are almost as common in Vojvodina as in Central Serbia, at 37 % and 41 % of all farms, respectively.

A more important difference between the provinces arises amongst medium-large farms: the most numerous size group in Central Serbia is medium-small farms of 2-5 ha, whilst in Vojvodina there is a more even spread of farms across the 2-5, 5-10 and 10-50 ha bands. This, plus the presence of very large farms in Vojvodina, serves to treble the average farm size from 4.3 ha in Central Serbia to 12.4 ha in Vojvodina.

In Central Serbia the average farm size coincides with the most numerous size group, whilst in Vojvodina relatively few farms are "average": most are smaller than 12.4 ha but a few are much larger.

Table 1. Farm size distribution, 2012 & 2018

Province Size group	Number of holdings						Agricultural area						Average size	
	2012			2018			2012			2018			2012	2018
	Number of farms	% of province	% of Serbia	Number of farms	% of province	% of Serbia	Area	% of province	% of Serbia	Area	% of province	% of Serbia		
Central Serbia	**483,928**	**100.0%**	**76.6%**	**437,413**	**100.0%**	**77.5%**	**1,828,527 ha**	**100.0%**	**53.2%**	**1,901,528 ha**	**100.0%**	**54.7%**	**3.8 ha**	**4.3 ha**
< 1 ha	131,106	27.1%	20.8%	86,941	19.9%	15.4%	73,869 ha	4.0%	2.1%	53,001 ha	2.8%	1.5%	0.6 ha	0.6 ha
1-2 ha	102,550	21.2%	16.2%	91,636	20.9%	16.2%	151,323 ha	8.3%	4.4%	135,731 ha	7.1%	3.9%	1.5 ha	1.5 ha
2-5 ha	154,220	31.9%	24.4%	153,851	35.2%	27.3%	503,363 ha	27.5%	14.6%	501,107 ha	26.4%	14.4%	3.3 ha	3.3 ha
5-10 ha	70,124	14.5%	11.1%	73,912	16.9%	13.1%	482,515 ha	26.4%	14.0%	508,574 ha	26.7%	14.6%	6.9 ha	6.9 ha
10-50 ha	25,226	5.2%	4.0%	30,090	6.9%	5.3%	398,209 ha	21.8%	11.6%	484,425 ha	25.5%	13.9%	15.8 ha	16.1 ha
> 50 ha	702	0.1%	0.1%	983	0.2%	0.2%	219,248 ha	12.0%	6.4%	218,689 ha	11.5%	6.3%	312 ha	222 ha
Vojvodina	**147,624**	**100.0%**	**23.4%**	**127,006**	**100.0%**	**22.5%**	**1,608,896 ha**	**100.0%**	**46.8%**	**1,574,366 ha**	**100.0%**	**45.3%**	**10.9 ha**	**12.4 ha**
< 1 ha	53,568	36.3%	8.5%	30,209	23.8%	5.4%	17,968 ha	1.1%	0.5%	10,966 ha	0.7%	0.3%	0.3 ha	0.4 ha
1-2 ha	21,169	14.3%	3.4%	16,592	13.1%	2.9%	30,462 ha	1.9%	0.9%	24,129 ha	1.5%	0.7%	1.4 ha	1.5 ha
2-5 ha	28,269	19.1%	4.5%	26,819	21.1%	4.8%	92,689 ha	5.8%	2.7%	88,139 ha	5.6%	2.5%	3.3 ha	3.3 ha
5-10 ha	18,959	12.8%	3.0%	21,601	17.0%	3.8%	134,766 ha	8.4%	3.9%	154,624 ha	9.8%	4.4%	7.1 ha	7.2 ha
10-50 ha	20,116	13.6%	3.2%	27,565	21.7%	4.9%	426,802 ha	26.5%	12.4%	558,371 ha	35.5%	16.1%	21.2 ha	20.3 ha
> 50 ha	5,543	3.8%	0.9%	4,220	3.3%	0.7%	906,209 ha	56.3%	26.4%	738,137 ha	46.9%	21.2%	163 ha	175 ha
SERBIA	**631,552**	**100.0%**		**564,419**	**100.0%**		**3,437,423 ha**	**100.0%**		**3,475,894 ha**	**100.0%**		**5.4 ha**	**6.2 ha**
< 1 ha	184,674	29.2%		117,150	20.8%		91,837 ha	2.7%		63,967 ha	1.8%		0.5 ha	0.5 ha
1-2 ha	123,719	19.6%		108,228	19.2%		181,785 ha	5.3%		159,860 ha	4.6%		1.5 ha	1.5 ha
2-5 ha	182,489	28.9%		180,670	32.0%		596,052 ha	17.3%		589,246 ha	17.0%		3.3 ha	3.3 ha
5-10 ha	89,083	14.1%		95,513	16.9%		617,281 ha	18.0%		663,198 ha	19.1%		6.9 ha	6.9 ha
10-50 ha	45,342	7.2%		57,655	10.2%		825,011 ha	24.0%		1,042,796 ha	30.0%		18.2 ha	18.1 ha
> 50 ha	6,245	1.0%		5,203	0.9%		1,125,457 ha	32.7%		956,827 ha	27.5%		180 ha	184 ha

Source: Republic Statistical Office; 2012 Agricultural Census & 2018 Farm Structures Survey

2.1.3 Farm economic structure

To understand how a farmer might respond to the availability of irrigation, it is important to consider the wider economic unit, whether a farm household or a legal entity. Two important criteria are the destination of output and the share of total income deriving from agriculture.

Share of output marketed

Both the Agricultural Census and the Farm Structures Survey asked respondents if they sold any of their output, and if so, whether they sold more than half or consumed most themselves. By 2018, the majority of farms in every size group marketed most of their produce, with almost all farms selling some of their output.

Across all farm sizes, 83 % of farms, managing 92 % of the total agricultural area, produced mainly for sale and so could be described as "commercial". The few farms that do consume most of their produce are typically small and mixed. A common feature of smaller farms in Serbia is that they produce some products, such as wheat or raspberries, for commercial sale, alongside others, such as pork or eggs, for household consumption. It is therefore more useful to think of commercial and non-commercial *enterprises* (types of crops or livestock) rather than commercial and non-commercial *holdings*.

Hence any division of Serbian agriculture into small "subsistence" farms and large "commercial" farms is not a very accurate reflection of reality. This also means that policies cannot really pursue a goal of trying to promote commercial farms, since the large majority of farms are already commercial.

Share of income from agriculture

The 1991 Agricultural Census asked each family holding whether its main source of income came from agriculture, from outside agriculture or whether it had mixed income with no one dominant source. This found that only 27 % of farm households got most of their income from agriculture, with this share falling to 25 % in Vojvodina.

This survey question has not been repeated for the last 30 years, though the 2019 Household Budget Survey shows that agriculture provided just 10 % of rural household income. This survey did not show what proportion of rural households got most of their income from agriculture, but it is consistent with the 30-year-old picture that the majority of farm households get their main income from a non-agricultural job, business or pension, with agriculture providing a supplementary income and some expenditure saving when food is consumed on the holding.

Thus mixed-income or "part-time" farming is the dominant situation in Serbia and can be found in holdings of all sizes: small farms rely on other income sources because they do not have sufficient land to live from farming alone; medium farms often have other business interests as well; and many of the largest farms are part of holding companies that have interests in food processing, retailing or other areas as well as farming.

The economic structure of farms can influence a farmer's response to irrigation opportunities through at least four factors: labour, capital, risk and reward, and access to markets.

Labour

If a farmer gains most of his or her income from a full-time job or non-farming business, then farming has to fit around this and use the time available in the evenings, weekends and holidays. The "opportunity cost" of giving up a job to focus on agriculture would be very high, including loss of a

regular monthly income and the health insurance, pension rights and other benefits that go with it. Farm families often look to get the best of both worlds, seeking ways to increase farm income whilst retaining the income and security of their other jobs. Much of the expansion of berry fruit production, and the more recent growth in high-value vegetables such as gherkins, has been driven by just this kind of part-time farming.

For a larger farm that provides the main occupation for at least one family member, labour is also a major constraint on the expansion of high-value fruits and vegetables. These crops need substantial inputs of labour at certain points in the cycle, particularly at planting and harvest, but there are several months when there is much less to do. This intermittent demand does not fit well with regular full-time labour and so has traditionally relied on seasonal casual labour, often using migrant workers from nearby countries like Bulgaria or Bosnia and Herzegovina. Many farmers report that this migrant labour is no longer available and that it is hard to find local casual labour due to the growth in non-farm employment. Even when casual labour is available, it brings management challenges with which many farmers would rather not deal.

There is therefore a strong tendency, across a wide range of farm sizes, to keep fruit and vegetable enterprises to a scale that can be managed by family labour alone. This is clearly shown by the fruit data from the 2018 Farm Structures Survey, which found that 64 % of all orchards and nut plantations were smaller than 0.3 ha, and that 58 % of the total fruit and nut area was grown in orchards[4] of less than 1 ha.

Relatively little fruit is grown in large orchards of 10-50 ha but there is an emerging sector of very large orchards (> 50 ha) for three specific types of fruit and nuts: hazelnuts, where 27 % of total area lies on plantations over 50 ha; apples, with 7 % in large orchards; and sour cherries with 5 %. These farms have a very different approach to labour and have made managing large numbers of casual workers a central part of their business model. However, very large orchards are still just the tip of the iceberg, even for hazelnuts, apples and sour cherries. All other fruit and nut species are grown almost entirely in small and medium-sized orchards.

The same level of detail is not available for vegetables, but the average area grown is 0.44 ha, compared to 0.68 ha for fruit. With vegetables, the big distinction will be between those whose production and harvesting can be fully mechanised, such as carrots and onions, and those needing a lot of manual labour, such as tomatoes, peppers, cucumbers, cabbages, strawberries, melons and watermelons.

Data presented in section 2.2.3 below show that, for both fruit and vegetables, the number of farms with these crops is increasing faster than the total crop area, and so the average area of fruit or vegetables per producing farm is falling. This indicates that the rapid expansion from 2012 to 2018 was driven more by new farms starting to grow small areas of fruit and vegetables, than by existing producers increasing their area. Labour constraints are almost certainly the main reason for this.

Capital

Someone who works full-time for an employer usually has no opportunity to invest in that business, but if they have land and a modest amount of capital to invest, then a small greenhouse, orchard or irrigation system can be an attractive opportunity to develop an income source of their own. However, if the farm family has its own non-agricultural business, then this will compete for the limited amount of capital available and may well offer better returns. The same conflict can occur even on the largest farms, where managers must decide whether to invest in the farming enterprise or in other parts of their business.

[4] The size of an "orchard" is calculated as the total area on the farm under one species of fruit or nuts, whether in one piece or in several parcels.

Risk and reward

Farming is risky by nature, due to its dependence on the weather and its susceptibility to pests, diseases and market fluctuations. When a family depends entirely on farming for its income, they have a strong incentive to maximise their income from agriculture but must also consider carefully whether a new venture would spread their risk or increase it. However, when the family gains most of its income from outside agriculture, as is usually the case, they may have less incentive to intensify their farm, but if they do try something new, there is less risk of a catastrophic drop in their income if it should go wrong.

This may influence which kinds of farms are most likely to be the innovators and early adopters of new irrigation technology or new high-value crops, which could help projects and extension services to target the most relevant farms.

Access to markets

Marketing can have a big influence on selling price and hence on total farm revenue. Here, large farms are generally at an advantage, as they have greater market power, can supply larger batches of consistent product, are more able to invest in storage and other ways of adding value, and may be able to supply direct to supermarkets or even export markets. Farmers' associations and cooperatives are often promoted as a way of bringing these advantages to small producers, and already play a significant role in some sectors and parts of Serbia.

However, they are just one option, and Serbia has succeeded in developing an efficient and competitive range of marketing channels that can aggregate produce from many small producers. The country's role as one of the world's largest exporters of raspberries is based on a network of cold stores spread throughout the producing areas, some run as cooperatives and some as private companies. This has made it possible for a working family to grow 0.1-0.2 ha of raspberries, tending them at the weekends and picking them during their summer holiday, and for these raspberries to end up fresh or frozen on supermarket shelves all over Europe. Similar developments in blackberries, blueberries, sour cherries, gherkins and other high-value products are increasingly allowing small, part-time farms to feed into sophisticated markets.

Because these marketing chains work, Serbia's small farm structure becomes an asset, in that it taps into a large pool of "spare time" family labour. A few hundred thousand families, each contributing a modest amount of labour per year, adds up to a very substantial labour force that has overcome the constraint of hired casual labour and allowed the rapid expansion of high-value fruit and vegetable production.

2.2 Farm and irrigation statistics

Detailed statistics on irrigation in Serbia have been collected twice since the breakup of Yugoslavia: in 2012 through a full Agricultural Census and in 2018 through a large Farm Structures Survey covering 120,000 household farms and legal entities[5]. Data were obtained by place, farm size, water source and method of irrigation, for 12 groups of irrigated crops.

The six-year period from 2012 to 2018 saw a dramatic and predominantly positive development of irrigation: the total irrigated area increased by 60 % from 100,000 ha to 160,000 ha and the number

[5] The Republic Statistical Office also publishes an annual statistical release on irrigation, but it covers only legal entities and hence omits the large majority of irrigating farms.

of irrigating farms increased by 92 % from 97,000 to 186,000. By 2018, one-third of all Serbian farms were making some use of irrigation.

As the number of farms grew faster than the area, the average irrigated area per irrigating farm fell by 17 % from 1.03 ha to 0.86 ha. This small average size of irrigated plots is closely connected with what is irrigated and how, and plays an important role in the economics of irrigation in Serbia. The most visible forms of irrigation – the giant centre-pivots and linear machines moving relentlessly over 100-hectare fields – play an important role for certain sectors such as seed production but are very much the exception.

2.2.1 Water source

Irrigation systems can be divided into two types: "Individual irrigation", where one farm is responsible for the whole process from abstracting the water to applying it to the crop, and "Multi-user irrigation", where an organisation abstracts the water and delivers it to multiple farms. Statistics distinguish four sources of water, which partially correspond to the type of irrigation (see also Table 2 at the end of this section):

- ***Groundwater on the holding*** is the most common water source, used by 98,000 farms for individual irrigation of 71,000 ha from private wells and boreholes (average 0.73 ha). It can be found wherever there is groundwater, but is most common over shallow alluvial aquifers where the costs of drilling a borehole and pumping water are low. Almost two-thirds of the area irrigated by groundwater on the holding lies in Central Serbia, with a third of the total in Šumadija and West Serbia.
- ***Surface water on the holding*** is a rather less common form of individual irrigation, since relatively few farms have a river running through or beside their land; it is used by 17,000 farms to irrigate 16,000 ha (average 0.90 ha). Almost 80 % of the area irrigated from this source lies in Central Serbia, with half of the total in Šumadija and West Serbia, where the relatively hilly ground creates many small rivers and streams.
- ***Surface water off the holding*** is the second most common source of water, used by 50,000 farms to irrigate 62,000 ha (average 1.24 ha). This category includes multi-user irrigation, predominantly from the Danube-Tisa-Danube (DTD) hydro-system in Vojvodina, together with individual irrigation systems where the farm has a pipe route to a nearby river or reservoir; many former kombinats have this form of irrigation. Two-thirds of the total area irrigated from surface water off the holding lies in Vojvodina, mainly due to the DTD system and other regional hydrosystems.
- ***Vodovod***, the public water-supply network, is used by 12,000 farms to irrigate 4,000 ha (average 0.30 ha). Some villages have constructed dual-purpose water supply systems, delivering a quality fit for drinking and a quantity scaled to the needs of small-scale irrigation. However, in most cases, these farms simply use ordinary tap water and pay normal water fees to irrigate small areas of very high value crops, such as greenhouses, nurseries and fruit and vegetables close to the house. Ninety percent of the area irrigated from Vodovod lies in Central Serbia, with more than half in Šumadija and West Serbia, where fruit production is particularly well developed. This system has some characteristics of multi-user irrigation, in that an organisation is responsible for delivering water to the farm, and some characteristics of individual irrigation, in that all irrigation-related decisions rest entirely with the farm.

Use of all four water sources increased substantially from 2012 to 2018.

Vode Vojvodine reported 100 users of the DTD hydro-system and regional systems in 2020, irrigating a total of 40,000 ha. Multi-user irrigation systems are much less common in Central Serbia, so the

total area under multi-user irrigation may be estimated at under 50,000 ha and the total number of users as less than 200. This means that three-quarters of all irrigated land and 99.9 % of all irrigating farms use some form of individual irrigation or Vodovod, rather than depending on an irrigation organisation.

Table 2. Source of irrigation water, 2012 & 2018

Province Size group	Number of irrigating holdings						Irrigated area						Av. irrig. area	
	2012			2018			2012			2018			2012	2018
	Number of farms	% of province	% of Serbia	Number of farms	% of province	% of Serbia	Irrigated area	% of province	% of Serbia	Irrigated area	% of province	% of Serbia		
Central Serbia	**87,492**	**100.0%**	**89.3%**	**166,123**	**100.0%**	**89.3%**	**41,522 ha**	**100.0%**	**89.3%**	**84,882 ha**	**100.0%**	**89.3%**	**0.5 ha**	**0.5 ha**
Groundwater	56,833	65.0%	50.0%	93,046	56.0%	50.0%	23,649 ha	57.0%	50.0%	49,185 ha	57.9%	50.0%	0.4 ha	0.5 ha
Groundwater on the holding	*49,019*	*56.0%*	*44.2%*	*82,182*	*49.5%*	*44.2%*	*22,771 ha*	*54.8%*	*44.2%*	*45,883 ha*	*54.1%*	*44.2%*	*0.5 ha*	*0.6 ha*
*Vodovod**	*7,814*	*8.9%*	*5.8%*	*10,864*	*6.5%*	*5.8%*	*878 ha*	*2.1%*	*5.8%*	*3,302 ha*	*3.9%*	*5.8%*	*0.1 ha*	*0.3 ha*
Surface water	27,309	31.2%	35.0%	65,089	39.2%	35.0%	16,716 ha	40.3%	35.0%	32,255 ha	38.0%	35.0%	0.6 ha	0.5 ha
Surface water on the holding	*6,461*	*7.4%*	*9.1%*	*16,992*	*10.2%*	*9.1%*	*4,296 ha*	*10.3%*	*9.1%*	*12,150 ha*	*14.3%*	*9.1%*	*0.7 ha*	*0.7 ha*
Surface water off the holding	*20,848*	*23.8%*	*25.8%*	*48,097*	*29.0%*	*25.8%*	*12,420 ha*	*29.9%*	*25.8%*	*20,105 ha*	*23.7%*	*25.8%*	*0.6 ha*	*0.4 ha*
Other	3,350	3.8%	4.3%	7,988	4.8%	4.3%	1,158 ha	2.8%	4.3%	3,442 ha	4.1%	4.3%	0.3 ha	0.4 ha
Vojvodina	**9,448**	**100.0%**	**10.7%**	**19,990**	**100.0%**	**10.7%**	**58,251 ha**	**100.0%**	**10.7%**	**74,705 ha**	**100.0%**	**10.7%**	**6.2 ha**	**3.7 ha**
Groundwater	7,682	81.3%	9.2%	17,111	85.6%	9.2%	17,857 ha	30.7%	9.2%	25,659 ha	34.3%	9.2%	2.3 ha	1.5 ha
Groundwater on the holding	*6,769*	*71.6%*	*8.4%*	*15,719*	*78.6%*	*8.4%*	*17,635 ha*	*30.3%*	*8.4%*	*25,272 ha*	*33.8%*	*8.4%*	*2.6 ha*	*1.6 ha*
*Vodovod**	*913*	*9.7%*	*0.7%*	*1,392*	*7.0%*	*0.7%*	*222 ha*	*0.4%*	*0.7%*	*387 ha*	*0.5%*	*0.7%*	*0.2 ha*	*0.3 ha*
Surface water	1,523	16.1%	1.2%	2,151	10.8%	1.2%	39,357 ha	67.6%	1.2%	45,261 ha	60.6%	1.2%	25.8 ha	21.0 ha
Surface water on the holding	*385*	*4.1%*	*0.2%*	*397*	*2.0%*	*0.2%*	*4,718 ha*	*8.1%*	*0.2%*	*3,508 ha*	*4.7%*	*0.2%*	*12.3 ha*	*8.8 ha*
Surface water off the holding	*1,138*	*12.0%*	*0.9%*	*1,754*	*8.8%*	*0.9%*	*34,638 ha*	*59.5%*	*0.9%*	*41,753 ha*	*55.9%*	*0.9%*	*30.4 ha*	*23.8 ha*
Other	243	2.6%	0.4%	728	3.6%	0.4%	1,038 ha	1.8%	0.4%	3,785 ha	5.1%	0.4%	4.3 ha	5.2 ha
SERBIA	**96,940**	**100.0%**		**186,113**	**100.0%**		**99,773 ha**	**100.0%**		**159,587 ha**	**100.0%**		**1.0 ha**	**0.9 ha**
Groundwater	64,515	66.6%		110,157	59.2%		41,506 ha	41.6%		74,844 ha	46.9%		0.6 ha	0.7 ha
Groundwater on the holding	*55,788*	*57.5%*		*97,901*	*52.6%*		*40,406 ha*	*40.5%*		*71,154 ha*	*44.6%*		*0.7 ha*	*0.7 ha*
*Vodovod**	*8,727*	*9.0%*		*12,256*	*6.6%*		*1,100 ha*	*1.1%*		*3,690 ha*	*2.3%*		*0.1 ha*	*0.3 ha*
Surface water	28,832	29.7%		67,240	36.1%		56,073 ha	56.2%		77,517 ha	48.6%		1.9 ha	1.2 ha
Surface water on the holding	*6,846*	*7.1%*		*17,389*	*9.3%*		*9,014 ha*	*9.0%*		*15,658 ha*	*9.8%*		*1.3 ha*	*0.9 ha*
Surface water off the holding	*21,986*	*22.7%*		*49,851*	*26.8%*		*47,059 ha*	*47.2%*		*61,858 ha*	*38.8%*		*2.1 ha*	*1.2 ha*
Other	3,593	3.7%		8,716	4.7%		2,195 ha	2.2%		7,227 ha	4.5%		0.6 ha	0.8 ha

Source: Republic Statistical Office; 2012 Agricultural Census & 2018 Farm Structures Survey

* The public water supply network, “Vodovod”, is mainly but not entirely sourced from groundwater.

2.2.2 *Irrigation method*

Both the 2012 Agricultural Census and the 2018 Farm Structures Survey found that the most common way of applying water to crops is surface irrigation (see Table 3 at the end of this section); in 2018, 71 % of irrigating farms used surface irrigation to some extent and 65 % used it as their sole means of irrigation, and 44 % of the total irrigated area was supplied by surface irrigation[6]. This method includes flood, furrow and basin irrigation and, on small areas of fruit and vegetables, simply laying a hosepipe on the ground and moving it periodically. Quick research by the strategy drafting team and the Agricultural Advisory Services found examples of surface irrigation on maize, blackberries, peppers and potatoes in several different municipalities. Users like this method because it is cheap and simple with nothing to go wrong, but it is most suitable where water is abundant and cheap. Farmers using surface irrigation require no special equipment, except perhaps a tractor-driven pump to lift water from a river or drainage ditch into their field, and so do not normally come into contact with irrigation designers, equipment suppliers or advisors, meaning that the scale of this form of irrigation is often overlooked.

Surface irrigation is used on a quarter of irrigated land in Vojvodina and on half of the irrigated area in Central Serbia, particularly in hilly areas where there is often scope to lead water from the river to the field by gravity.

The 2018 survey found that 29 % of irrigating farms used some form of pressurised irrigation (sprinkler, drip or both) on 36 % of the overall irrigated area, plus 6 % of farms that used pressurised irrigation on some plots and surface irrigation on others. There is a wide range of technologies used for pressurised irrigation in Serbia:

- Sprinkler systems include large centre-pivots and linear irrigation machines, hose-reel systems (often referred to as “Tifons”), rain guns, moveable aluminium pipes with sprinklers on risers, and micro-sprinkler systems with plastic pipes. Sprinkler irrigation is particularly common on larger fields and arable crops, so 80 % of the total area under sprinklers lies in Vojvodina[7].
- Drip systems range from permanent installations for orchards and vineyards, some of which are designed by specialists and fitted with sophisticated control systems, to single-use drip tape for vegetables, which a farmer can buy in a local shop and install himself; this category also includes mini-sprinklers, which are often used on vegetables. Because of the focus on fruits and vegetables, 70 % of the drip irrigated area lies in Central Serbia[8].
- Fertigation is becoming increasingly common with drip systems of all kinds and is occasionally also used with micro-sprinkler and sprinkler systems.

Pressurised systems cost more to install and maintain than surface irrigation but they can save labour, and their ability to deliver water and nutrients where and when required can bring a significant increase in yields which, for intensive high-value crops, may more than offset their costs.

Of the 60,000 ha of new irrigated area added from 2012 to 2018, more than half (36,000 ha) used surface irrigation. The second-biggest increase was in drip irrigation, for which the area trebled from 11,000 to 34,000 ha. The area irrigated on farms that used exclusively sprinkler irrigation fell by a quarter (12,000 ha), which may be due to a combination of at least three factors:

6 Excluding farms that used both surface and pressurised irrigation, for which the area under surface irrigation is not known.

7 Calculation excludes farms that used other forms of irrigation as well as sprinkler.

8 Calculation excludes farms that used other forms of irrigation as well as drip.

- Some farms may have considered it was not worth irrigating arable crops in relatively wet 2018, compared to relatively dry 2012[9];
- Some farms will have switched from sprinkler to drip or mini-sprinklers, often along with a change in the crops grown;
- Some farms will have added other forms of irrigation as well as sprinklers, moving them out of the sprinkler-only category.

[9] In harvest year 2011-12, precipitation was 20 % below average, whilst in 2017-18 it was 20 % above.

Table 3. Irrigation method, 2012 & 2018

Province Size group	Number of irrigating holdings						Irrigated area						Av. irrig. area	
	2012			2018			2012			2018			2012	2018
	Number of farms	% of province	% of Serbia	Number of farms	% of province	% of Serbia	Irrigated area	% of province	% of Serbia	Irrigated area	% of province	% of Serbia		
Central Serbia	**87,492**	**100.0%**	**90.3%**	**166,123**	**100.0%**	**89.3%**	**41,522 ha**	**100.0%**	**41.6%**	**84,882 ha**	**100.0%**	**53.2%**	**0.5 ha**	**0.5 ha**
Surface	53,762	61.4%	55.5%	108,671	65.4%	58.4%	16,248 ha	39.1%	16.3%	43,652 ha	51.4%	27.4%	0.3 ha	0.4 ha
Pressurised	26,290	30.0%	27.1%	47,702	28.7%	25.6%	19,296 ha	46.5%	19.3%	32,422 ha	38.2%	20.3%	0.7 ha	0.7 ha
Sprinkler	*6,384*	*7.3%*	*6.6%*	*7,192*	*4.3%*	*3.9%*	*9,284 ha*	*22.4%*	*9.3%*	*6,609 ha*	*7.8%*	*4.1%*	*1.5 ha*	*0.9 ha*
Drip	*18,052*	*20.6%*	*18.6%*	*38,518*	*23.2%*	*20.7%*	*7,506 ha*	*18.1%*	*7.5%*	*23,625 ha*	*27.8%*	*14.8%*	*0.4 ha*	*0.6 ha*
Sprinkler & drip	*1,854*	*2.1%*	*1.9%*	*1,992*	*1.2%*	*1.1%*	*2,506 ha*	*6.0%*	*2.5%*	*2,188 ha*	*2.6%*	*1.4%*	*1.4 ha*	*1.1 ha*
Mixed	7,440	8.5%	7.7%	9,750	5.9%	5.2%	5,979 ha	14.4%	6.0%	8,809 ha	10.4%	5.5%	0.8 ha	0.9 ha
Vojvodina	**9,448**	**100.0%**	**9.7%**	**19,990**	**100.0%**	**10.7%**	**58,251 ha**	**100.0%**	**58.4%**	**74,705 ha**	**100.0%**	**46.8%**	**6.2 ha**	**3.7 ha**
Surface	3,478	36.8%	3.6%	12,000	60.0%	6.4%	8,608 ha	14.8%	8.6%	17,695 ha	23.7%	11.1%	2.5 ha	1.5 ha
Pressurised	5,347	56.6%	5.5%	6,872	34.4%	3.7%	45,834 ha	78.7%	45.9%	46,019 ha	61.6%	28.8%	8.6 ha	6.7 ha
Sprinkler	*1,937*	*20.5%*	*2.0%*	*1,350*	*6.8%*	*0.7%*	*35,774 ha*	*61.4%*	*35.9%*	*26,269 ha*	*35.2%*	*16.5%*	*18.5 ha*	*19.5 ha*
Drip	*2,965*	*31.4%*	*3.1%*	*5,155*	*25.8%*	*2.8%*	*3,749 ha*	*6.4%*	*3.8%*	*10,203 ha*	*13.7%*	*6.4%*	*1.3 ha*	*2.0 ha*
Sprinkler & drip	*445*	*4.7%*	*0.5%*	*367*	*1.8%*	*0.2%*	*6,311 ha*	*10.8%*	*6.3%*	*9,547 ha*	*12.8%*	*6.0%*	*14.2 ha*	*26.0 ha*
Mixed	623	6.6%	0.6%	1,118	5.6%	0.6%	3,808 ha	6.5%	3.8%	10,990 ha	14.7%	6.9%	6.1 ha	9.8 ha
SERBIA	**96,940**	**100.0%**		**186,113**	**100.0%**		**99,773 ha**	**100.0%**		**159,587 ha**	**100.0%**		**1.0 ha**	**0.9 ha**
Surface	57,240	59.0%		120,671	64.8%		24,856 ha	24.9%		61,347 ha	38.4%		0.4 ha	0.5 ha
Pressurised	31,637	32.6%		54,574	29.3%		65,130 ha	65.3%		78,441 ha	49.2%		2.1 ha	1.4 ha
Sprinkler	*8,321*	*8.6%*		*8,542*	*4.6%*		*45,058 ha*	*45.2%*		*32,878 ha*	*20.6%*		*5.4 ha*	*3.8 ha*
Drip	*21,017*	*21.7%*		*43,673*	*23.5%*		*11,254 ha*	*11.3%*		*33,828 ha*	*21.2%*		*0.5 ha*	*0.8 ha*
Sprinkler & drip	*2,299*	*2.4%*		*2,359*	*1.3%*		*8,817 ha*	*8.8%*		*11,735 ha*	*7.4%*		*3.8 ha*	*5.0 ha*
Mixed	8,063	8.3%		10,868	5.8%		9,787 ha	9.8%		19,799 ha	12.4%		1.2 ha	1.8 ha

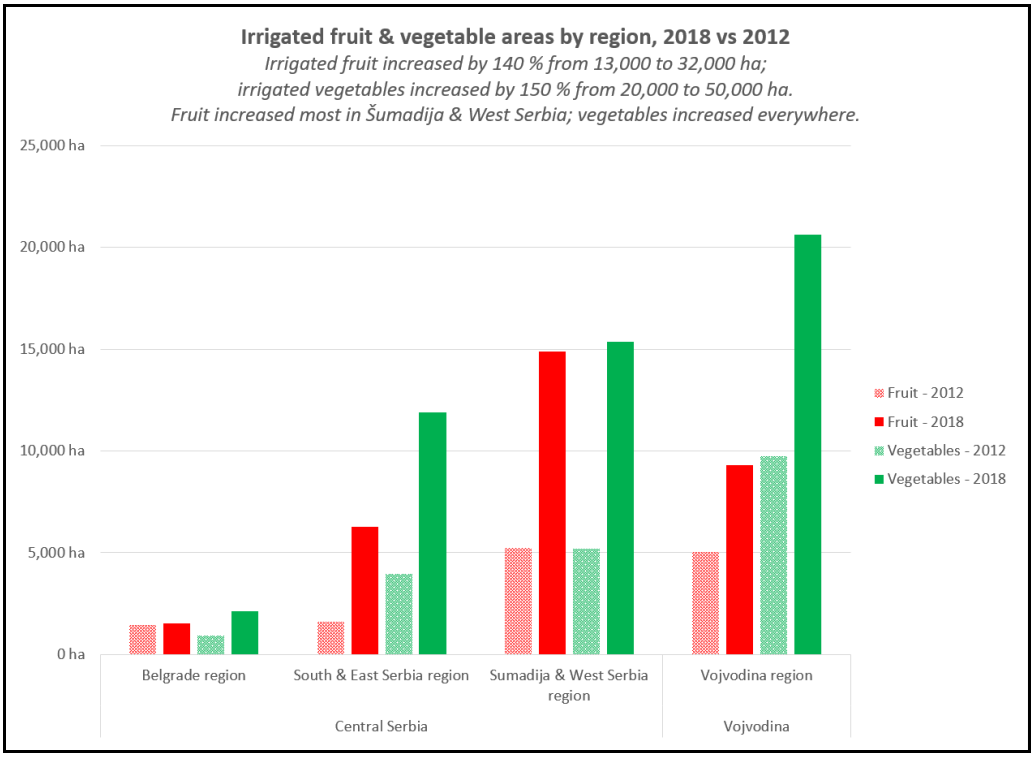
Source: Republic Statistical Office; 2012 Agricultural Census & 2018 Farm Structures Survey

2.2.3 *Crops irrigated*

The share of annual and perennial crops irrigated in Serbia rose from 3.4 % in 2012 to 4.6 % in 2018, meaning that more than 95 % of total crop area is still rainfed rather than irrigated. However, the share that is irrigated varies greatly between crops:

- Irrigation is very rarely used on sunflower (0.9 % of total sunflower area was irrigated in 2018), cereals other than maize (1.7 %), forage crops and other crops (1.6 %), since the economic response to irrigation of these crops is generally low.
- Irrigation is occasionally used on maize (3.0 %) and vineyards (3.3 %). Irrigation of maize seems to be largely confined to maize grown for seed and to places where irrigation can be delivered very cheaply, for example, by gravity-fed surface irrigation. Irrigation of wine grapes increases yield but reduces quality, particularly sugar content, and so is not widely practised.
- Irrigation is used on a significant minority of the area under sugar beet (12 %), fruit (17 %), potatoes (21 %) and legumes (25 %). These are all crops that can be grown successfully without irrigation, but which give a good response where irrigation can be provided at reasonable cost.
- Irrigation is now used on 93 % of vegetables, a marked increase from the figure of 57 % just six years before. Irrigation of vegetables increases yield, improves quality and makes both yield and quality more consistent; it is hence now regarded as essential for the commercial production of most kinds of vegetable.

Of the 60,000 ha increase in irrigation from 2012 to 2018, more than 80 % was on high-value crops, with an additional 30,000 ha of irrigated vegetables and 19,000 ha of irrigated fruit. This shows that irrigation is being increasingly concentrated on those crops for which it gives the greatest return, with the increase in irrigated fruit and vegetables being found across all four regions of Serbia, as shown in Слика 2:



Слика 2. Change in irrigated fruit & vegetable areas by region; *Source: Data from Republic Statistical Office, Agricultural Census 2012 & Farm Structures Survey 2018*

It is notable that 83 % of the total fruit area is still not irrigated. Fruit may offer the greatest potential for the profitable expansion of irrigation, but there are two major obstacles to consider:

- Most fruit production is found in areas of low hills, with almost half of the total in the region of Šumadija and West Serbia. Shallow groundwater is often not available and rivers run along the bottom of valleys, so a farmer who wants to irrigate an existing orchard may need to bring water across several people's land and lift it a considerable height, as well as facing the risk that the river may run dry in the height of summer just when irrigation is needed most.
- The majority of the top fruit area is under plums, apples and sour cherries, often with old, large, widely-spaced and rather unproductive trees in a relatively low-input, low-output system. In this situation, the cost of running irrigation from tree to tree would be high relative to the value of the additional output (berry fruits are typically closely spaced and intensive, so if water can be brought to the plot, the cost of distributing it to the plants is not high relative to their output).

This suggests two situations in which irrigated fruit production could be profitably expanded

1) Where irrigation can be brought to existing orchards at reasonable cost, either through individual irrigation or through small local schemes that can capture water upstream and supply it by gravity;
2) Where farmers establish new intensive orchards in areas where water is readily available, with irrigation used from the outset.

From 2012 to 2018, the total area of fruit grew by 16,000 ha and the area of irrigated fruit grew by 19,000 ha; this shows that part of the increase was from adding irrigation to existing orchards but suggests that the majority came from planting of new orchards with irrigation.

Looking at other crops, the change in irrigated area from 2012 to 2018 was generally in line with overall changes in the crop area, i.e., a reduction in the area under maize and an increase in other cereals, and a reduction in the area of sugar beet and an increase in oilseed rape and sunflower. Irrigated soya is included in "other crops", so it is not possible to see how this changed.

Crops irrigated on holdings with irrigation

The tendency for irrigation to be concentrated on certain crops applies on individual farms as well as to the country overall. Farms that use irrigation tend to irrigate almost all of their vegetable area, around a third of their sugar beet, legumes, potatoes and vegetables, and less than one-tenth of their cereals and oilseeds. This may be due to a combination of three main factors:

- Even where irrigation is available, it has a cost in terms of time and often also energy for pumping; farmers may consider that the extra yield from irrigating low-value crops does not justify the costs of irrigation.
- The total amount of irrigation that farmers can deliver may be limited by their water supply, their irrigation equipment or both; in this case farmers would rationally use their limited resource on those crops that respond to it best.
- Serbian farms are typically composed of multiple parcels scattered over a wide area and not all will have equal access to irrigation; farmers will tend to match the irrigation and the crops, for example,investing in a borehole only on the parcel where fruit is planted, or using land close to the river to grow fruit and vegetables.

Section 2.1.3 noted that, rather than trying to classify farms as "commercial" or "subsistence", it is more useful to think of commercial and non-commercial enterprises within one farm. The same

applies to irrigation: with one-third of Serbian farms now using irrigation but typically using it on only a small part of their land, it may be more useful to think in terms of irrigated or rainfed plots and crops, rather than irrigating versus non-irrigating holdings.

Irrigated area and number of irrigating holdings by crop

Figure 3 shows, for each crop group, the total irrigated area (blue column), the number of holdings irrigating this crop (grey column) and the average area of this crop irrigated by these holdings (green column, right-hand axis):

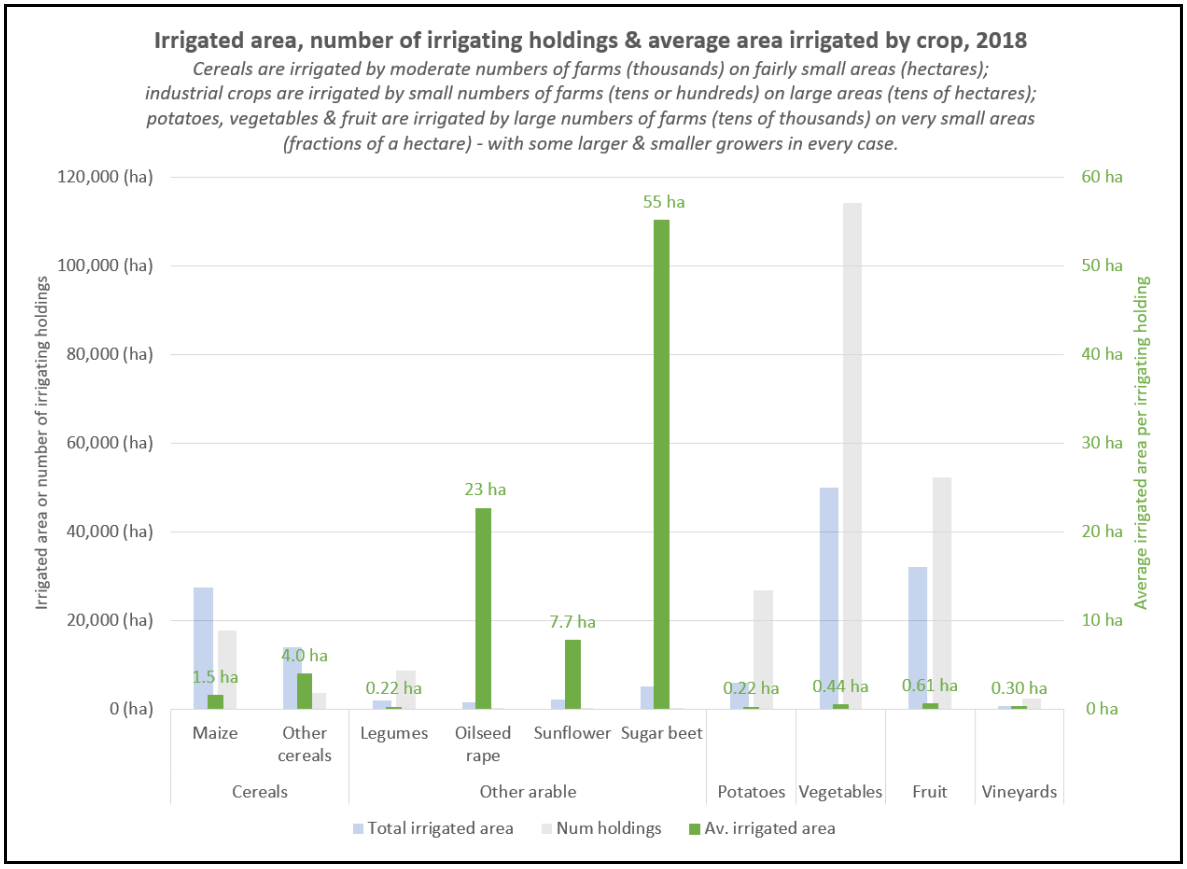


Figure 3. Irrigated area, number of irrigating holdings & average irrigated area by crop; *Source: Data from Republic Statistical Office, Farm Structures Survey 2018*

Looking at farm numbers, irrigation is most common on vegetables (114,000 holdings), fruit (52,000) and potatoes (27,000). Vegetables alone account for half of all irrigated plots[10] and the high-value crops together account for 87 % of plots. Of the arable crops, most often irrigated are maize (18,000), legumes (9,000) and other cereals (4,000); forage and other crops are not shown here as the group is very heterogeneous.

In terms of irrigated area, vegetables (50,000 ha) and fruit (32,000 ha) again dominate, with maize (27,000 ha) and other cereals (14,000 ha) in third and fourth place. Irrigated legumes, oilseeds and sugar beet together account for only 8 % of irrigated area (11,000 ha) because legumes are usually grown on small areas and the other crops are grown by relatively few farms.

The average area of irrigated high-value crops is very small: 0.2 ha of potatoes, 0.4 ha of vegetables and 0.6 ha of fruit, with 0.3 ha of vines in the rare case that grapes are actually irrigated. The

[10] The term "plot" is used here to describe one kind of crop grown on one farm, even if spread across multiple parcels of land.

structure of irrigated fruit and vegetable production in Serbia consists mainly of tens of thousands of very small producers, who together produce substantial volumes for marketing and export.

Irrigated arable crops fall into two distinct groups:

- Maize, other cereals and legumes are grown by many small producers as well as by large farms, so the average areas are small (0.2 ha of legumes, 1.5 ha of maize and 4.0 ha of other cereals);
- Industrial crops are grown by a few large farms and so the average areas irrigated are large (an average of 8 ha of sunflower on 265 farms, 55 ha of sugar beet on 94 farms and just 23 ha of oilseed rape on 69 farms irrigating this crop).

The generally small areas irrigated per farm has important implications for water use, as discussed in section 2.2.5 below.

Table 4. Irrigated crops, 2012 & 2018

Province / Size group	Number of irrigating holdings (not additive across crops)						Irrigated area						Av. irrig. area	
	2012			2018			2012			2018			2012	2018
	Number of farms	% of province	% of Serbia	Number of farms	% of province	% of Serbia	Irrigated area	% of province	% of Serbia	Irrigated area	% of province	% of Serbia		
Central Serbia	**87,492**	**100.0%**	**90.3%**	**166,123**	**100.0%**	**89.3%**	**41,522 ha**	**100.0%**	**41.6%**	**84,882 ha**	**100.0%**	**53.2%**	**0.5 ha**	**0.5 ha**
Cereals							14,092 ha	33.9%	14.1%	21,227 ha	25.0%	13.3%		
Maize	*14,786*	*16.9%*	*15.3%*	*16,882*	*10.2%*	*9.1%*	*12,262 ha*	*29.5%*	*12.3%*	*13,738 ha*	*16.2%*	*8.6%*	*0.8 ha*	*0.8 ha*
Other cereals	*2,201*	*2.5%*	*2.3%*	*3,219*	*1.9%*	*1.7%*	*1,830 ha*	*4.4%*	*1.8%*	*7,489 ha*	*8.8%*	*4.7%*	*0.8 ha*	*2.3 ha*
Other arable							1,239 ha	3.0%	1.2%	1,801 ha	2.1%	1.1%		
Legumes	*4,562*	*5.2%*	*4.7%*	*8,460*	*5.1%*	*4.5%*	*349 ha*	*0.8%*	*0.4%*	*656 ha*	*0.8%*	*0.4%*	*0.1 ha*	*0.1 ha*
Oilseed rape	*436*	*0.5%*	*0.4%*	*17*	*0.0%*	*0.0%*	*74 ha*	*0.2%*	*0.1%*	*144 ha*	*0.2%*	*0.1%*	*0.2 ha*	*8.5 ha*
Sunflower	*23*	*0.0%*	*0.0%*	*159*	*0.1%*	*0.1%*	*58 ha*	*0.1%*	*0.1%*	*998 ha*	*1.2%*	*0.6%*	*2.5 ha*	*6.3 ha*
Sugar beet	*21*	*0.0%*	*0.0%*	*19*	*0.0%*	*0.0%*	*758 ha*	*1.8%*	*0.8%*	*3 ha*	*0.0%*	*0.0%*	*36.1 ha*	*0.2 ha*
Potatoes	18,579	21.2%	19.2%	25,485	15.3%	13.7%	3,910 ha	9.4%	3.9%	3,921 ha	4.6%	2.5%	0.2 ha	0.2 ha
Vegetables	37,184	42.5%	38.4%	100,980	60.8%	54.3%	10,110 ha	24.3%	10.1%	29,411 ha	34.6%	18.4%	0.3 ha	0.3 ha
Forage & other							3,751 ha	9.0%	3.8%	5,316 ha	6.3%	3.3%		
Fruit	15,819	18.1%	16.3%	47,089	28.3%	25.3%	8,295 ha	20.0%	8.3%	22,657 ha	26.7%	14.2%	0.5 ha	0.5 ha
Vineyards	533	0.6%	0.5%	1,939	1.2%	1.0%	126 ha	0.3%	0.1%	548 ha	0.6%	0.3%	0.2 ha	0.3 ha
Vojvodina	**9,448**	**100.0%**	**9.7%**	**19,990**	**100.0%**	**10.7%**	**58,251 ha**	**100.0%**	**58.4%**	**74,705 ha**	**100.0%**	**46.8%**	**6.2 ha**	**3.7 ha**
Cereals							22,062 ha	37.9%	22.1%	20,071 ha	26.9%	12.6%		
Maize	*893*	*9.5%*	*0.9%*	*749*	*3.7%*	*0.4%*	*16,662 ha*	*28.6%*	*16.7%*	*13,575 ha*	*18.2%*	*8.5%*	*18.7 ha*	*18.1 ha*
Other cereals	*248*	*2.6%*	*0.3%*	*320*	*1.6%*	*0.2%*	*5,400 ha*	*9.3%*	*5.4%*	*6,495 ha*	*8.7%*	*4.1%*	*21.8 ha*	*20.3 ha*
Other arable							10,447 ha	17.9%	10.5%	8,924 ha	11.9%	5.6%		
Legumes	*106*	*1.1%*	*0.1%*	*259*	*1.3%*	*0.1%*	*799 ha*	*1.4%*	*0.8%*	*1,278 ha*	*1.7%*	*0.8%*	*7.5 ha*	*4.9 ha*
Oilseed rape	*4*	*0.0%*	*0.0%*	*52*	*0.3%*	*0.0%*	*600 ha*	*1.0%*	*0.6%*	*1,419 ha*	*1.9%*	*0.9%*	*150.0 ha*	*27.3 ha*
Sunflower	*43*	*0.5%*	*0.0%*	*106*	*0.5%*	*0.1%*	*614 ha*	*1.1%*	*0.6%*	*1,048 ha*	*1.4%*	*0.7%*	*14.3 ha*	*9.9 ha*
Sugar beet	*147*	*1.6%*	*0.2%*	*75*	*0.4%*	*0.0%*	*8,433 ha*	*14.5%*	*8.5%*	*5,179 ha*	*6.9%*	*3.2%*	*57.4 ha*	*69.1 ha*
Potatoes	1,109	11.7%	1.1%	1,243	6.2%	0.7%	2,391 ha	4.1%	2.4%	1,974 ha	2.6%	1.2%	2.2 ha	1.6 ha
Vegetables	3,875	41.0%	4.0%	13,194	66.0%	7.1%	9,755 ha	16.7%	9.8%	20,618 ha	27.6%	12.9%	2.5 ha	1.6 ha
Forage & other							8,459 ha	14.5%	8.5%	13,675 ha	18.3%	8.6%		
Fruit	2,121	22.4%	2.2%	5,070	25.4%	2.7%	5,050 ha	8.7%	5.1%	9,312 ha	12.5%	5.8%	2.4 ha	1.8 ha
Vineyards	247	2.6%	0.3%	353	1.8%	0.2%	89 ha	0.2%	0.1%	131 ha	0.2%	0.1%	0.4 ha	0.4 ha

Province / Size group	Number of irrigating holdings (not additive across crops)						Irrigated area						Av. irrig. area	
	2012			2018			2012			2018			2012	2018
	Number of farms	% of province	% of Serbia	Number of farms	% of province	% of Serbia	Irrigated area	% of province	% of Serbia	Irrigated area	% of province	% of Serbia		
SERBIA	**96,940**	**100.0%**		**186,113**	**100.0%**		**99,773 ha**	**100.0%**		**159,587 ha**	**100.0%**		**1.0 ha**	**0.9 ha**
Cereals							36,154 ha	36.2%		41,298 ha	25.9%			
Maize	*15,679*	*16.2%*		*17,631*	*9.5%*		*28,923 ha*	*29.0%*		*27,313 ha*	*17.1%*		*1.8 ha*	*1.5 ha*
Other cereals	*2,449*	*2.5%*		*3,539*	*1.9%*		*7,230 ha*	*7.2%*		*13,985 ha*	*8.8%*		*3.0 ha*	*4.0 ha*
Other arable							11,686 ha	11.7%		10,726 ha	6.7%			
Legumes	*4,668*	*4.8%*		*8,719*	*4.7%*		*1,149 ha*	*1.2%*		*1,934 ha*	*1.2%*		*0.2 ha*	*0.2 ha*
Oilseed rape	*440*	*0.5%*		*69*	*0.0%*		*674 ha*	*0.7%*		*1,563 ha*	*1.0%*		*1.5 ha*	*22.7 ha*
Sunflower	*66*	*0.1%*		*265*	*0.1%*		*672 ha*	*0.7%*		*2,047 ha*	*1.3%*		*10.2 ha*	*7.7 ha*
Sugar beet	*168*	*0.2%*		*94*	*0.1%*		*9,191 ha*	*9.2%*		*5,182 ha*	*3.2%*		*54.7 ha*	*55.1 ha*
Potatoes	19,688	20.3%		26,728	14.4%		6,301 ha	6.3%		5,895 ha	3.7%		0.3 ha	0.2 ha
Vegetables	41,059	42.4%		114,174	61.3%		19,865 ha	19.9%		50,030 ha	31.3%		0.5 ha	0.4 ha
Forage & other							12,209 ha	12.2%		18,991 ha	11.9%			
Fruit	17,940	18.5%		52,159	28.0%		13,344 ha	13.4%		31,968 ha	20.0%		0.7 ha	0.6 ha
Vineyards	780	0.8%		2,292	1.2%		215 ha	0.2%		680 ha	0.4%		0.3 ha	0.3 ha

Source: Republic Statistical Office; 2012 Agricultural Census & 2018 Farm Structures Survey

Geographical distribution of irrigated crops

Figure 4 below shows the distribution of irrigated crops divided into three broad groups (arable and forage crops; fruit and grapes; vegetables and potatoes), with each dot representing 10 ha of irrigated crop. Data are from the 2018 Farm Structures Survey for each of the 186 municipalities outside Kosovo, with random location of dots within municipality boundaries:

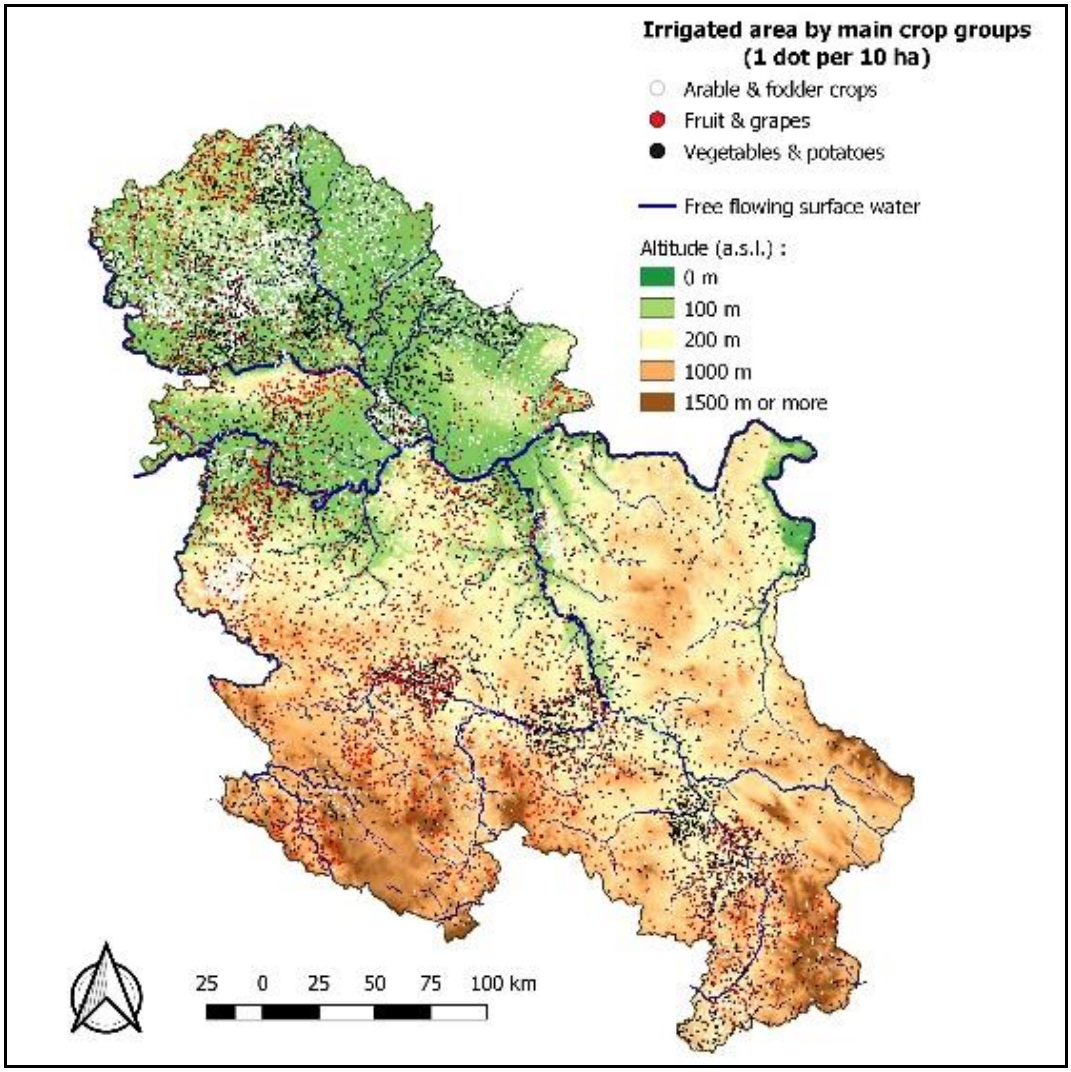


Figure 4. Geographical distribution of irrigated crops in Serbia; *Source: 2018 Farm Structures Survey; municipality-level data..*

Irrigated ***arable and forage crops*** are concentrated in two main locations:

- In Vojvodina, particularly areas of north-east Vojvodina covered by the Danube-Tisa-Danube (DTD) hydro-system;
- North of Belgrade in "Pančkevaćki rit", where much of the irrigation lies land of the former "PKB" agro-kombinat, which was the largest in Yugoslavia.

Irrigated ***vegetables and potatoes*** are mainly clustered along major rivers and above alluvial aquifers, where there are suitable soils and a ready source of irrigation water. These areas include:

- Along the Danube, Tisa, Begej and Tamiš rivers in Vojvodina;
- On both banks of the Sava, in Vojvodina and in Central Serbia, including Šabac municipallity;
- Along the Morava rivers, including the municipalities of Čačak, Trstenik, Žitorada and Leskovac.

Irrigated ***fruit and grape***s are clustered in several locations, particularly:

- Subotica municipality in North-east Vojvodina;
- Fruška Gora in Vojvodina;
- South of the Sava around Šabac;
- Around Čačak and Zlatibor on the West Morava and its tributaries;
- Around Leskovac on the South Morava.

2.2.4 Interactions between size, crop, water source and irrigation method

The choice of what farms grow, and whether and how they irrigate, is strongly correlated with farm size. Some of these effects are directly driven by size, whilst others stem from the fact that most of Serbia's largest farms are in Vojvodina, where terrain, soils and water sources also influence crop and irrigation choices. Table 5 presents overall data on irrigation by farm size.

Farm size and cropping mix

There is a strong relationship between farm size and cropping mix, regardless of irrigation.

As shown in Figure 5, the smallest farms devote more than a quarter of their land area to high-value fruit, vegetables, potatoes and grapes; this proportion declines steadily with farm size as larger farms place increasing emphasis on arable and forage crops. For small farms, high value crops and livestock give the opportunity to generate more income from a small area of land, whilst family labour is often sufficient to manage a moderate area of fruits and vegetables and a few livestock. With increasing size, farms look to substitute capital for labour and most choose to grow crops that are easy to mechanize, easy to manage and easy to market. The graph also shows that farms over 10 ha grow a higher share of "other arable" crops (oilseeds, legumes and sugar beet), which give a higher return than cereals but can still be fully mechanised.

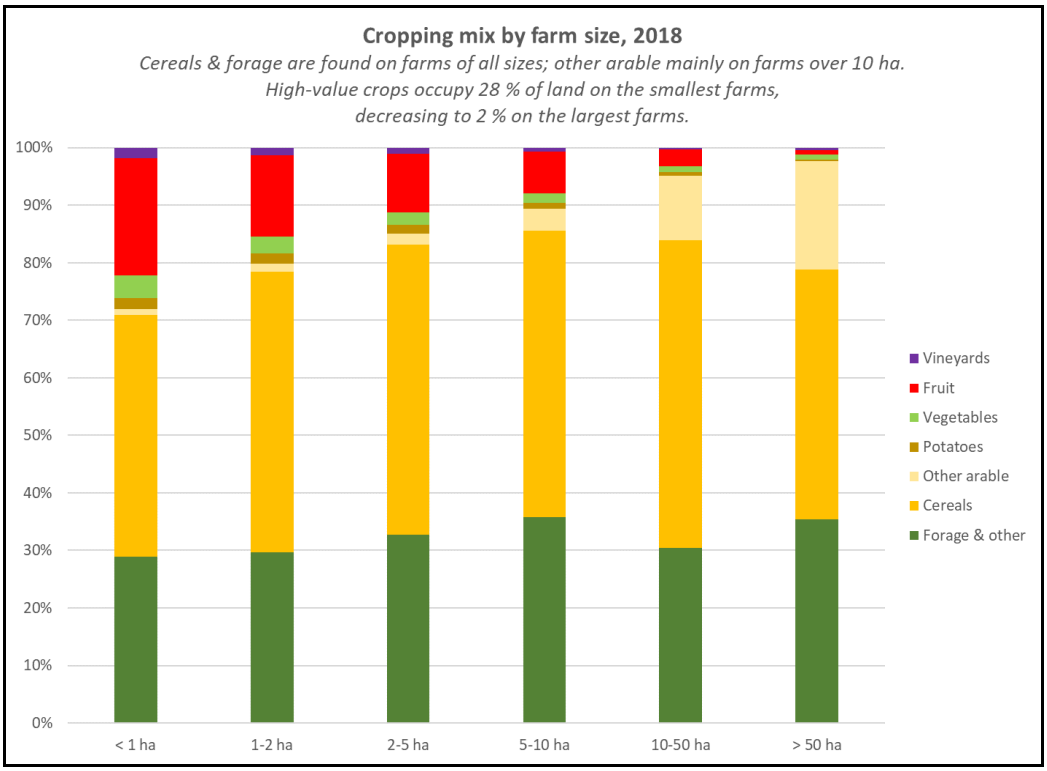


Figure 5. Cropping mix by farm size; *Source: Data from Republic Statistical Office, Farm Structures Survey 2018*

When this size-related cropping trend is combined with the fact that irrigation is most commonly used on vegetables, fruit and potatoes, the result is a very strong link between farm size and the choice of irrigated crops, as shown in Figure 6:

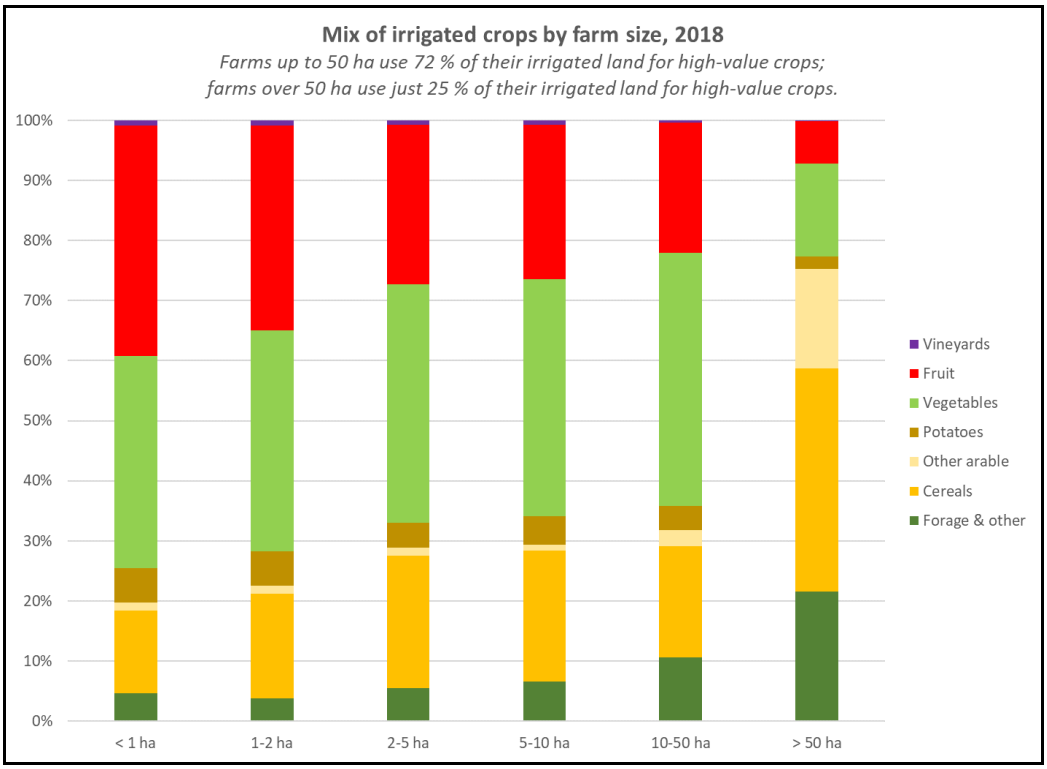


Figure 6. Mix of irrigated crops by farm size; *Source: Data from Republic Statistical Office, Farm Structures Survey 2018*

Very small farms (under 1 ha) use 80 % of their irrigated land for high-value crops. This share falls steadily with farm size up to 50 ha, at which point the share under high-value crops drops dramatically from 68 % to 25 %; these very large farms use most of their irrigated land for cereals, other arable and forage crops.

Considering the total irrigated area irrespective of farm size, 56 % of the total is used for high-value crops (vegetables 31 %, fruit 20 %, potatoes 4 %, vineyards 0.4 %) and 44 % used for low-value crops (cereals 26 %, other arable 7 %, forage and other 12 %).

Water source

There is a clear correlation between water source and cropping mix, with 69 % of the area irrigated from groundwater growing high-value crops, whilst 68 % of the area using surface water is under low-value crops.

There is also a strong correlation between water source and farm size: farms up to 50 ha irrigate mainly from groundwater, with just 35 % of their irrigated area supplied from surface water. For farms over 50 ha the situation is very different, with 82 % of their irrigated area using surface water; the majority of these farms are located in Vojvodina and get their water from the DTD or regional hydro-systems, so most of their irrigated area is supplied by surface water from off the holding.

Irrigation method

Very similar correlations exist with irrigation method. The link between cropping pattern and irrigation method is shown in Figure 7[11]:

[11] Statistics record irrigation method at the level of the farm not the crop so, for example, the first column actually shows that 58 % of the area of irrigated potatoes lies on farms that use exclusively surface irrigation. Where a farm uses only one form of irrigation the results are unequivocal, but where a farm uses, say, both sprinkler and drip, it is quite possible that sprinkler irrigation is used for one crop and drip irrigation for another.

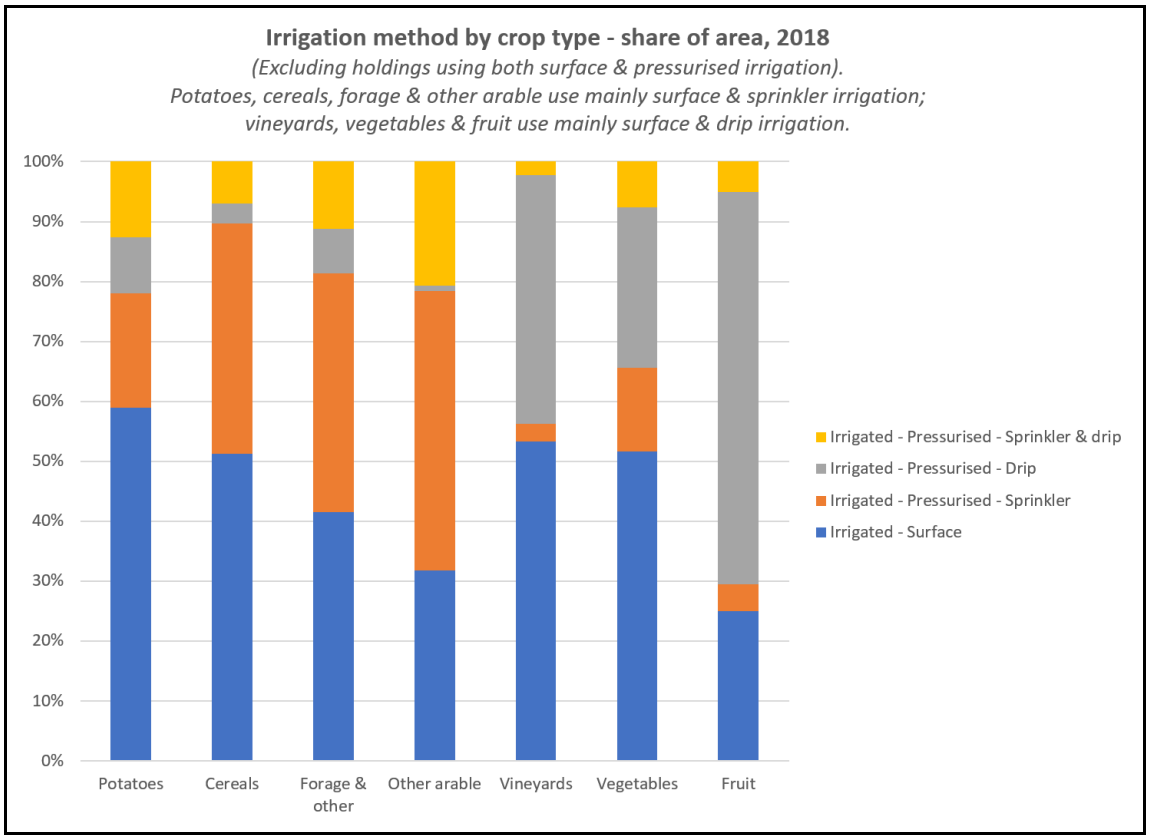


Figure 7. Irrigation method by crop type; *Source: Data from Republic Statistical Office, Farm Structures Survey 2018*

This shows that arable crops use mainly surface and sprinkler irrigation, with potatoes in particular tending to use surface irrigation. High-value grapes, vegetables and fruit use mainly drip and surface irrigation, with drip irrigation dominant for fruit production.

Because larger farms tend to focus on arable crops, this suggests that surface and sprinkler irrigation are more likely to be found on large farms, with drip more common on small farms. The data show exactly this; leaving aside those farms that use multiple irrigation methods, the statistics show that:

- Farms up to 50 ha use surface irrigation for 56 % of their irrigated area, drip for 34 % and sprinklers for just 10 %, with a tendency for the use of sprinkler irrigation to grow with farm size. This fits with small farms' preference for irrigation systems that are cheap and simple, even if somewhat time-consuming, plus their widespread use of drip irrigation on fruit and vegetables.
- Farms over 50 ha use sprinklers for 63 % of the area, surface irrigation for 28 % and drip irrigation for just 9 %. This is in line with their focus on large-scale, highly mechanised arable production.

Overall picture

At the risk of over-generalising, most irrigating farms in Serbia can be put into one of two groups:

- Large farms applying mainly surface water to cereals and other low-value arable crops by surface and sprinkler irrigation. Most of the very large irrigating farms are found in Vojvodina and use surface water from off the holding, delivered to the farm by the DTD and regional hydro-systems.

- Small farms throughout Serbia applying mainly groundwater to high-value fruit and vegetables, through drip and other irrigation methods.

There are many exceptions, such as small farms irrigating cereals and large farms using groundwater, but these two groups represent the most common patterns of irrigation found in Serbia.

Table 5. Irrigation by farm size, 2012 & 2018

Province Size group	Number of irrigating holdings						Irrigated area						Av. irrig. area	
	2012			2018			2012			2018			2012	2018
	Number of farms	% of province	% of Serbia	Number of farms	% of province	% of Serbia	Irrigated area	% of province	% of Serbia	Irrigated area	% of province	% of Serbia		
Central Serbia	**87,492**	**100.0%**	**90.3%**	**166,123**	**100.0%**	**89.3%**	**41,522 ha**	**100.0%**	**41.6%**	**84,882 ha**	**100.0%**	**53.2%**	**0.5 ha**	**0.5 ha**
< 1 ha	20,401	23.3%	21.0%	25,326	15.2%	13.6%	2,993 ha	7.2%	3.0%	6,020 ha	7.1%	3.8%	0.1 ha	0.2 ha
1-2 ha	17,839	20.4%	18.4%	34,430	20.7%	18.5%	4,467 ha	10.8%	4.5%	11,002 ha	13.0%	6.9%	0.3 ha	0.3 ha
2-5 ha	29,781	34.0%	30.7%	62,647	37.7%	33.7%	11,825 ha	28.5%	11.9%	28,660 ha	33.8%	18.0%	0.4 ha	0.5 ha
5-10 ha	13,893	15.9%	14.3%	31,060	18.7%	16.7%	8,963 ha	21.6%	9.0%	20,491 ha	24.1%	12.8%	0.6 ha	0.7 ha
10-50 ha	5,438	6.2%	5.6%	12,393	7.5%	6.7%	7,133 ha	17.2%	7.1%	13,499 ha	15.9%	8.5%	1.3 ha	1.1 ha
> 50 ha	140	0.2%	0.1%	267	0.2%	0.1%	6,142 ha	14.8%	6.2%	5,210 ha	6.1%	3.3%	44 ha	20 ha
Vojvodina	**9,448**	**100.0%**	**9.7%**	**19,990**	**100.0%**	**10.7%**	**58,251 ha**	**100.0%**	**58.4%**	**74,705 ha**	**100.0%**	**46.8%**	**6.2 ha**	**3.7 ha**
< 1 ha	3,055	32.3%	3.2%	3,976	19.9%	2.1%	638 ha	1.1%	0.6%	1,005 ha	1.3%	0.6%	0.2 ha	0.3 ha
1-2 ha	1,094	11.6%	1.1%	2,389	12.0%	1.3%	666 ha	1.1%	0.7%	1,373 ha	1.8%	0.9%	0.6 ha	0.6 ha
2-5 ha	1,593	16.9%	1.6%	4,120	20.6%	2.2%	1,637 ha	2.8%	1.6%	3,266 ha	4.4%	2.0%	1.0 ha	0.8 ha
5-10 ha	1,297	13.7%	1.3%	4,064	20.3%	2.2%	2,197 ha	3.8%	2.2%	5,472 ha	7.3%	3.4%	1.7 ha	1.3 ha
10-50 ha	1,830	19.4%	1.9%	4,833	24.2%	2.6%	7,573 ha	13.0%	7.6%	14,031 ha	18.8%	8.8%	4.1 ha	2.9 ha
> 50 ha	579	6.1%	0.6%	608	3.0%	0.3%	45,539 ha	78.2%	45.6%	49,559 ha	66.3%	31.1%	79 ha	82 ha
SERBIA	**96,940**	**100.0%**		**186,113**	**100.0%**		**99,773 ha**	**100.0%**		**159,587 ha**	**100.0%**		**1.0 ha**	**0.9 ha**
< 1 ha	23,456	24.2%		29,302	15.7%		3,631 ha	3.6%		7,025 ha	4.4%		0.2 ha	0.2 ha
1-2 ha	18,933	19.5%		36,819	19.8%		5,133 ha	5.1%		12,375 ha	7.8%		0.3 ha	0.3 ha
2-5 ha	31,374	32.4%		66,767	35.9%		13,462 ha	13.5%		31,926 ha	20.0%		0.4 ha	0.5 ha
5-10 ha	15,190	15.7%		35,124	18.9%		11,160 ha	11.2%		25,963 ha	16.3%		0.7 ha	0.7 ha
10-50 ha	7,268	7.5%		17,226	9.3%		14,706 ha	14.7%		27,530 ha	17.3%		2.0 ha	1.6 ha
> 50 ha	719	0.7%		875	0.5%		51,681 ha	51.8%		54,769 ha	34.3%		72 ha	63 ha

Source: Republic Statistical Office; 2012 Agricultural Census & 2018 Farm Structures Survey

2.2.5 *Water use*

The 2012 Agricultural Census asked farmers for their total water use over the year. As most water use is not metered, the enumerators helped the farmers to estimate consumption from the type of crops grown and the number of irrigations. The results were inevitably approximate and so the Statistical Office decided not to repeat this question in the 2018 Farm Structures Survey. Hence the numbers in this section assume that application rates per crop in 2018 were the same as the average application rate in 2012 for farms in the same oblast and size group, using the same water source and irrigation method[12]. They should therefore be taken as indicative, rather than precise.

Figure 8 below shows estimated water use by source, and how this changed as the irrigated area increased from 2012 to 2018:

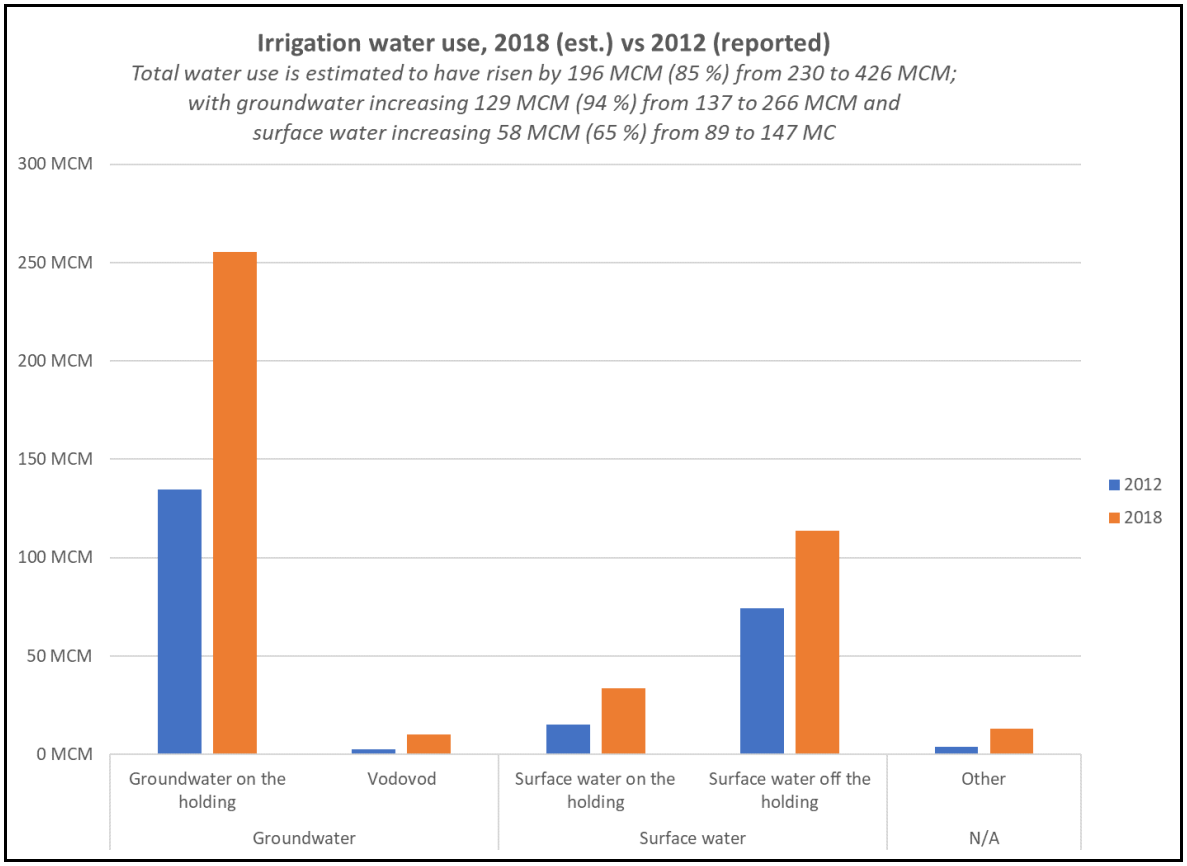


Figure 8. Irrigation water use in 2018 vs 2012; *Source: Data from Republic Statistical Office, Agricultural Census 2012 & Farm Structures Survey 2018*

Процењује се да се укупна потрошња воде повећала за 85%, где се потрошња подземне воде повећала нешто брже од потрошње површинске воде, тако да се из подземних вода сада снабдева 64% целокупног наводњавања у односу на 61% током 2012. године.

Total water use is estimated to have increased by 85 %, with groundwater use increasing slightly faster than surface water, so that groundwater now supplies 64 % of all irrigation versus 61% in 2012.

[12] Water use was recorded in 2012 at the level of the farm, not the crop. Where a farm irrigated only one type of crop, calculated application rates will be correct, but if a farm irrigated, for example, both maize and fruit, this approach will tend to over-estimate water use on maize and under-estimate use on fruit. However, the data were stratified by size and there is a strong tendency for small farms to irrigate "thirsty" high-value crops and large farms to irrigate less thirsty low-value crops, so the error should not be too large.

Individual irrigation increased its water use by nearly 140 million cubic metres (MCM) from ground- and surface water on the holding, plus some water from other sources. An additional 40 MCM were supplied from surface water off the holding, with much of this coming from the DTD and other hydro-systems.

The estimated total water use of 426 MCM represents the amount delivered by 5 mm of precipitation across Serbia – slightly less than falls in two typical rainy days. Expressed in terms of surface water, it is roughly equal to one day's flow of the Danube as it leaves Serbia.

Water use per irrigating farm

As shown above, most farms irrigate quite small crop areas; this results in rather low total water use per farm:

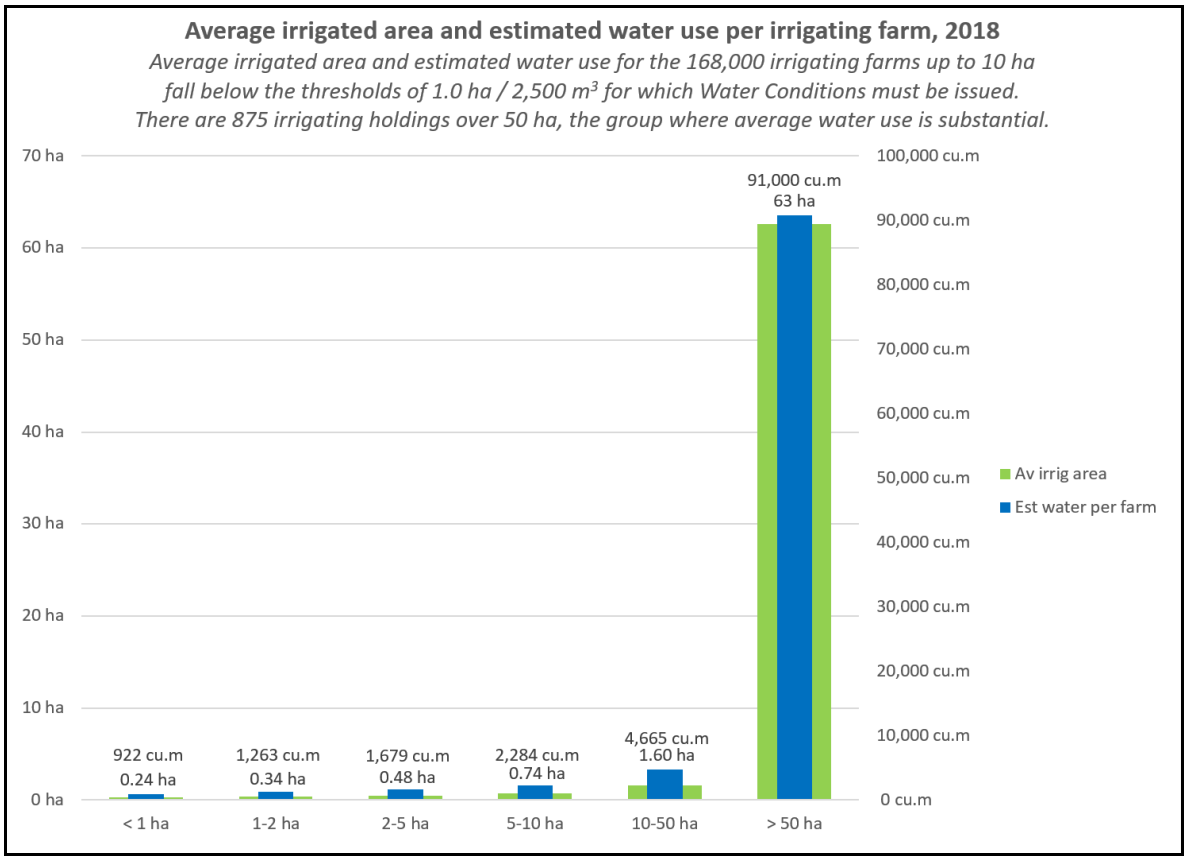


Figure 9. Average irrigated area and estimated water use per farm; *Source: Estimated from data provided by the Republic Statistical Office, Agricultural Census 2012 & Farm Structures Survey 2018*

Three distinct groups can be identified:

- ***168,000 farms up to 10 ha*** each irrigate on average less than one hectare and use less than 2,500 m^3 per year, placing most of them below the size threshold at which a farm is legally obliged to apply for "Water Conditions".
- ***17,000 farms of 10-50 ha*** each irrigate on average 1.6 ha and use less than 5,000 m^3 per year.
- ***900 farms over 50 ha*** each irrigate an average of 63 ha and use just over 90,000 m^3 per year.

Numbers show the average irrigated area and water use across all irrigating farms of a given size, so within each size class there will be some farms that irrigate more and some that irrigate less. However, it is likely that there are only around 1,000 farms in the country that use substantial quantities of water for irrigation. This includes 140 very large farms in Vojvodina that are supplied by surface water off the holding, usually meaning the DTD and other hydro-systems, so the total number of farms using substantial quantities of water from unlicensed sources is probably less than 1,000. Many of these abstract directly from major rivers or from alluvial aquifers that are linked to major rivers, so the number of farms at risk of depleting scarce aquifers or harming the ecology of local rivers is may be no more than a few hundred.

Total water use by farm size

Whilst large farms individually use more water, small farms are much more numerous. Farms up to 5 ha account for 70 % of all irrigating farms and just over 40 % of total irrigation water use. For the size groups above 5 ha, the increase in water use per farm is almost exactly balanced by the decrease in number of farms, so that each of the groups 5-10 ha, 10-50 ha and over 50 ha uses around 20 % of total irrigation water.

Interaction between water source, irrigation method and application rate

As noted above, there is tendency for small farms to irrigate high-value crops with groundwater by drip irrigation, whilst large farms irrigate low-value crops with surface water by sprinkler. High-value crops typically have much higher irrigation requirements than arable crops, so this results in average application rates per hectare being higher on small farms, higher for groundwater than for surface water, and higher for drip than for other forms of irrigation. This does not conflict with the general principle that drip irrigation has higher field efficiency than sprinkler or surface irrigation, but simply reflects the fact that drip irrigation is most often used on “thirsty” fruit and vegetable crops.

Water use by crop

Estimated water use per crop is shown in Figure 10:

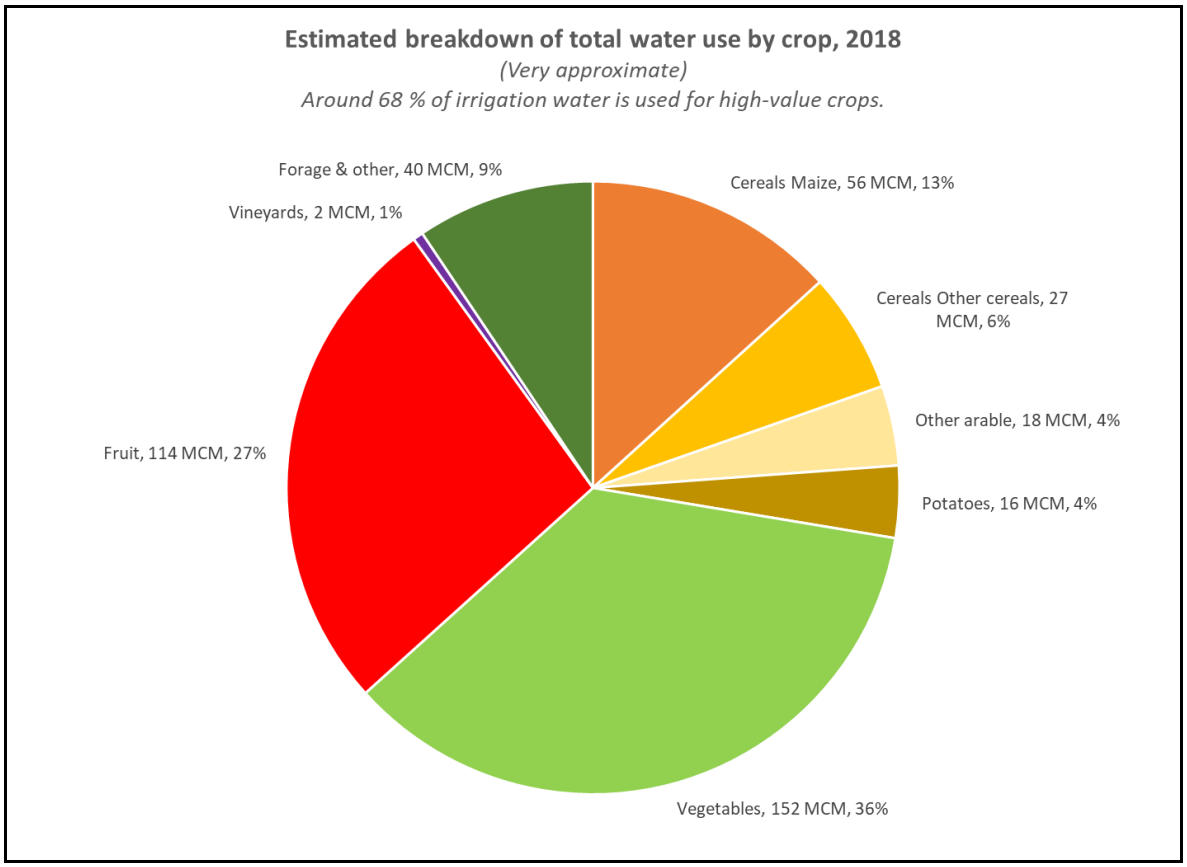


Figure 10. Estimated breakdown of water use per crop; *Source: Estimated from data provided by the Republic Statistical Office, Agricultural Census 2012 & Farm Structures Survey 2018*

High-value crops – vegetables, fruit, potatoes and grapes – together receive more than two-thirds of total water used for irrigation, showing that the water resource and the associated inputs of capital, labour and energy are effectively targeted at the crops where they bring the greatest return.

2.2.6 Output value

Official statistics do not record separately the yields or output value of irrigated versus rainfed crops, but the Statistical Office does calculate Standard Output per crop by the Eurostat methodology, for each of Serbia's two "NUTS 2" regions (RS1 - North and RS2 - South). A review of multiple published sources gave approximate ratios of irrigated to rainfed yields for each region, allowing estimation of separate Standard Outputs for rainfed and irrigated crops. Figure 11 shows the resultant values:

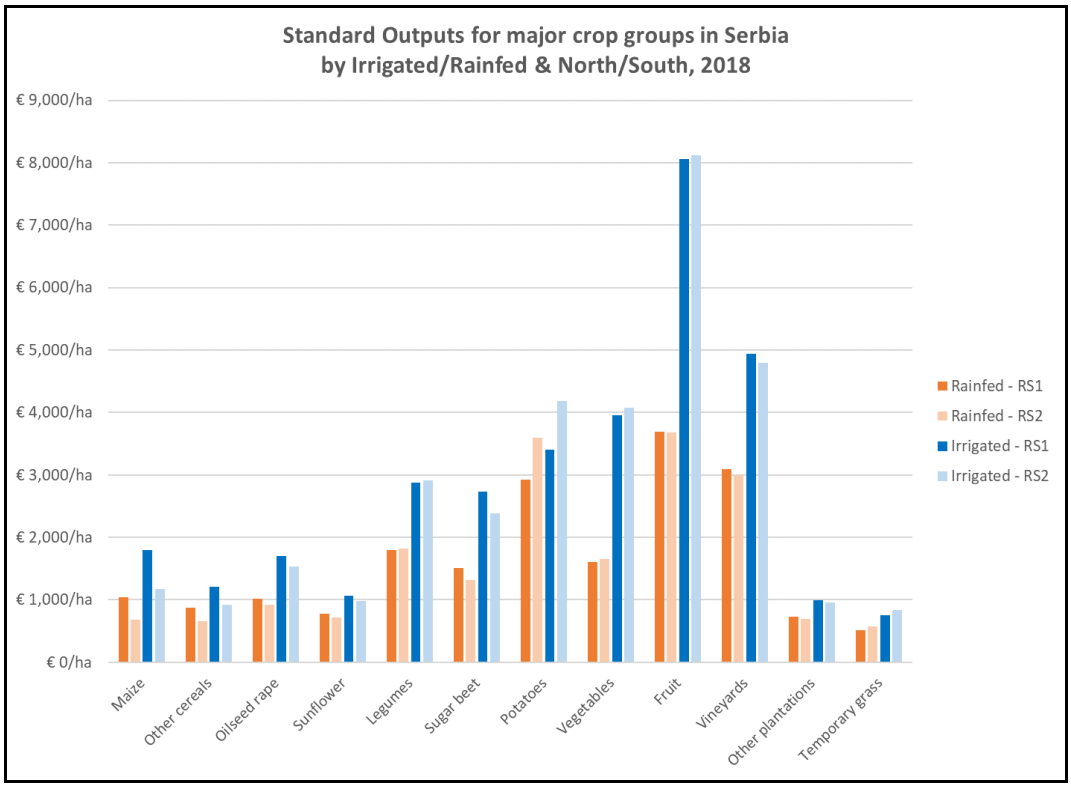


Figure 11. Estimated Standard Outputs by crop group; *Source: Estimated from data provided by the Republic Statistical Office and other sources*

Maize, other cereals and oilseeds can accurately be described as low-value crops, given that their rainfed Standard Outputs are generally below € 1,000/ha, with irrigation increasing output by around half.

Legumes and sugar beet offer higher returns of around € 1,500/ha when rainfed and approaching € 3,000/ha with irrigation.

Potatoes, fruit and vineyards constitute high-value crops even without irrigation, with returns of over € 3,000/ha. Irrigation substantially increases returns and more than doubles the revenue from fruit, taking it above € 8,000/ha.

Vegetables are an interesting case, in that without irrigation their revenue is similar to that from legumes or sugar beet, at slightly more than € 1,500/ha. However, more than 90 % of Serbia's vegetable area is now irrigated, raising Standard Output to around € 4,000/ha and so clearly qualifying as a high-value crop.

Looking at the economic benefit of irrigation:

- Irrigating small-grain cereals and oilseeds[13] increases revenue by € 500/ha or less and irrigating maize brings a benefit of under € 1,000/ha, explaining why these crops are so rarely irrigated.
- Irrigating vegetables increases revenue by € 2-3,000/ha and clearly shows why vegetables are so often irrigated. First estimates for grapes also show a benefit of € 2-3,000/ha but this might be reduced by quality effects.
- Irrigating potatoes and fruit brings an even higher benefit of € 3-4,000/ha.

[13] This figure excludes soya, which was recorded under "Other crops" in the irrigation section of the 2018 Farm Structure Survey and typically shows a higher response to irrigation.

This shows that farmers' decisions of what and what not to irrigate are quite rationale. It again raises the question of whether there is scope to further increase the area of irrigated fruit and also suggests that there could be considerable benefit in increasing the share of potatoes that is irrigated above its current modest level of 21 %.

Total output value from irrigation

Figure 12 shows estimates of the total value of output by crop in 2018, for both rainfed and irrigated production. It should be noted that this excludes the large and heterogenous group of "forage and other" and hence does not include the substantial output value of several important crops such as soya, lucerne and forage maize, resulting in a value that is not directly comparable with other estimates of total crop output.

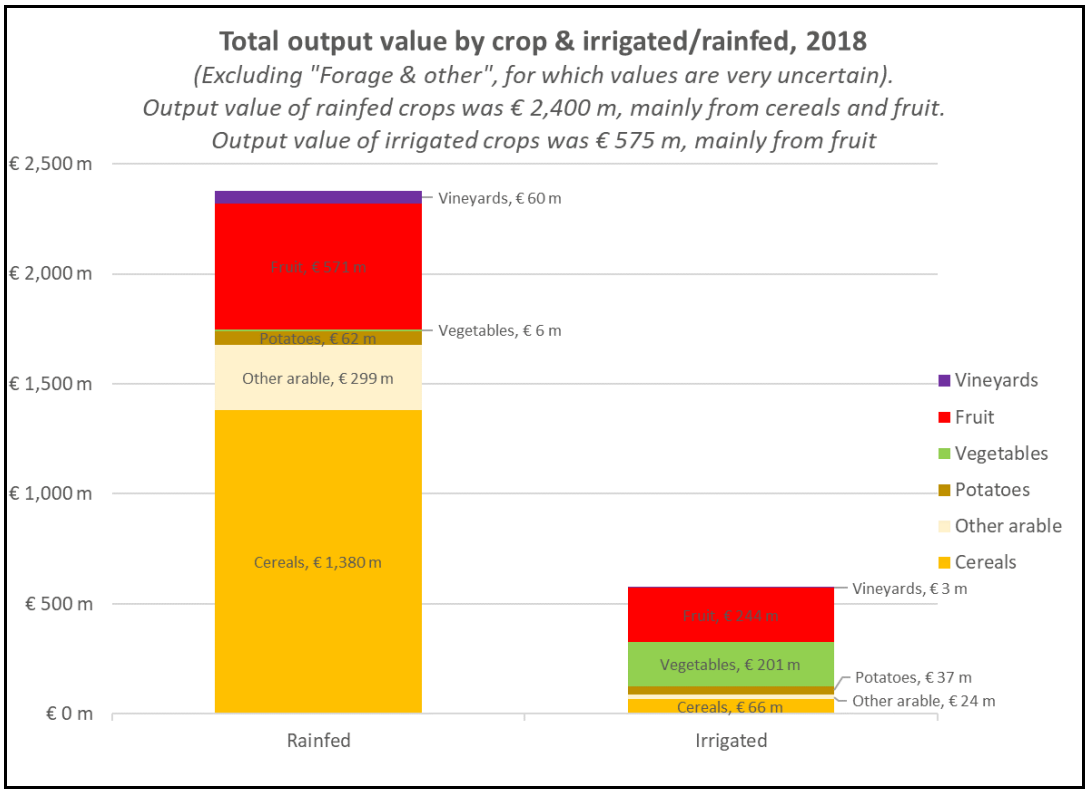


Figure 12. Total output value by crop, irrigated & rainfed; *Source: Estimated from data provided by the Republic Statistical Office and other sources*

The overall value of irrigated output from these crops is estimated at € 575 million, meaning that irrigated agriculture produces 16 % of crop output value from 6 % of total crop area. It also shows the very different structure of output when irrigation is used:

- For rainfed production, 71 % of value comes from cereals and other arable, and 24 % from fruit;
- For irrigated production, 44 % of value comes from fruit, 35 % from vegetables and just 16 % from arable crops.

Output value and farm size

The correlation between farm size and cropping mix presented earlier translates into a clear correlation between size and irrigated output value per hectare. The smallest farms (< 1 ha) appear

to have the highest output value per hectare, at around € 5,000/ha. This declines steadily with size to a value of € 4,000/ha for farms of 10-50 ha and then drops sharply to around € 2,500/ha for the largest farms, in line with the switch from high-value crops to arable. In reality, the drop-off for the largest farms may not be quite as dramatic, due to somewhat higher yields, the production of seed crops and occasional double-cropping, which was not recorded in the statistical surveys.

The trade-off between size and intensity means that the total value of irrigated output is spread right across the size range. Around one-fifth of total value is produced each by farms of up to 2 ha, 2-5 ha, 5-10 ha, 10-50 ha and over 50 ha, with a slightly higher contribution from farms of 2-5 ha (very numerous) and lower contribution from farms under 1 ha (very small).

How irrigation increases output per hectare

Farmers can benefit from irrigation in two main ways: they can continue to grow the same crops but benefit from higher yields, quality and consistency, or they can switch to higher-value crops for which yield and quality would be unacceptably low or variable without irrigation. Figure 13 aims to show the relative importance of these two effects:

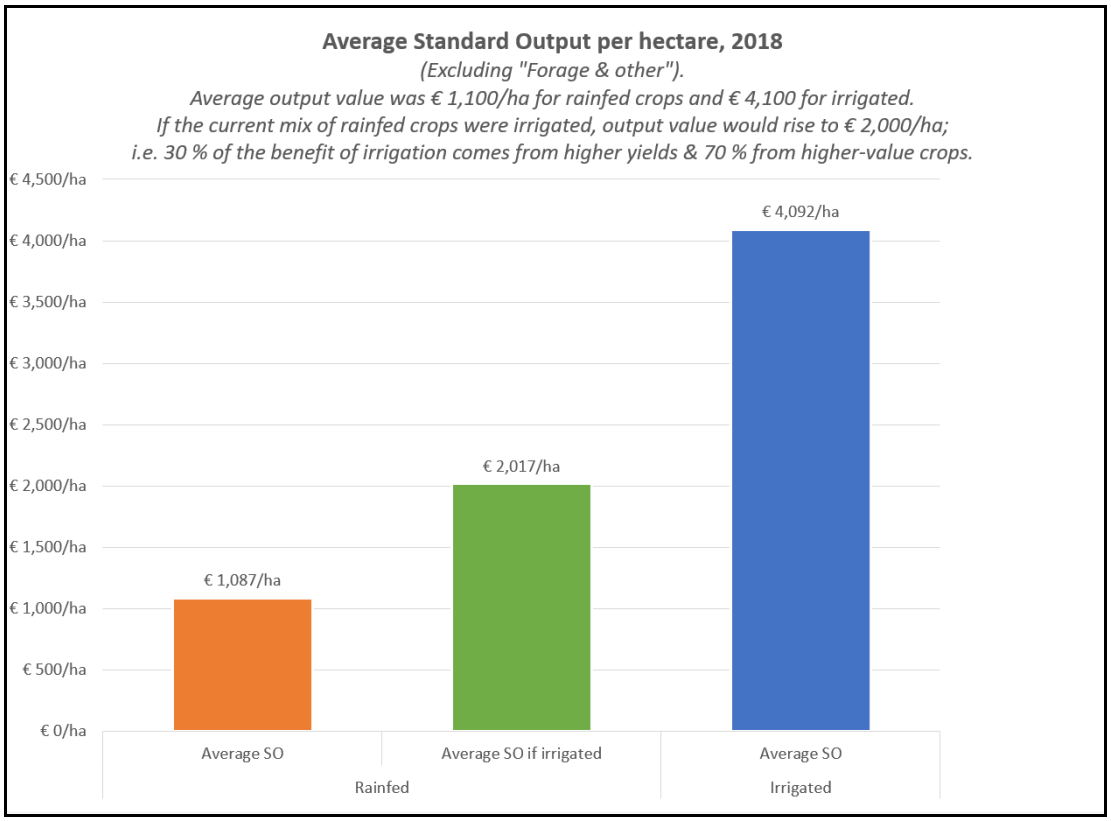


Figure 13. Impact of irrigation on Standard Output per hectare; *Source: Estimated from data provided by the Republic Statistical Office and other sources*

The first column shows the overall average Standard Output for rainfed production in Serbia: around € 1,100/ha. The second column shows what would happen if the cropping mix were kept the same but yields increased through irrigation: average output would rise by € 1,000/ha. The third column shows what actually happens when Serbian farmers irrigate; yield rises by not € 1,000/ha but € 3,000/ha as irrigating farmers grow a different and much higher-value mixture of crops. In broad terms, it may be said that 30 % of the benefit of irrigation comes from higher yields and 70 % from the ability to grow higher-value crops.

3 PUBLIC IRRIGATION SYSTEMS

The large majority of Serbia's land supplied by public irrigation systems lies in Vojvodina and is managed by Vode Vojvodine. This section briefly describes the most important systems there; a more comprehensive database of public systems will be included in the Programme document.

Hydrosystems

Vode Vojvodine manages three large hydrosystems:

- ***DTD Hydrosystem***: The Danube-Tisa-Danube canal was originally built for navigation, to shorten the route for barges travelling up and down the Danube. It was quickly expanded to provide a drainage network for much of Vojvodina, and then progressively developed for irrigation. The system now comprises the main navigation route plus a number of linked canals.
- ***North Bačka Regional Hydrosystem***: This covers land in Vojvodina north of the Danube and west of the DTD canal, through a network of drainage and irrigation canals linked to the DTD canal and to local rivers,
- ***Banat Regional Hydrosytem***: This cover land east of the DTD canal, in the same way.

Figure 14 gives a map of the DTD Hydrosystem. The wider lines denote navigable rivers or canal stretches; the thinner lines show irrigation and drainage canals or rivers.

Figure 14. Map of the DTD canal system

The two regional hydrosystems are divided into 12 sub-systems:

Banat Hydrosystem

- Banat
- Kikinda
- Nadela
- Nova Crnja-Žitište
- Novi Kneževac

Severna Bačka Hydrosystem

- Ada
- Beljanska bara
- Mali Iđoš
- Plazović
- Srbobran
- Telečka
- Tisa – Palić

Figure 15 shows the seven sub-systems of the North Bačka Hydrosystem:

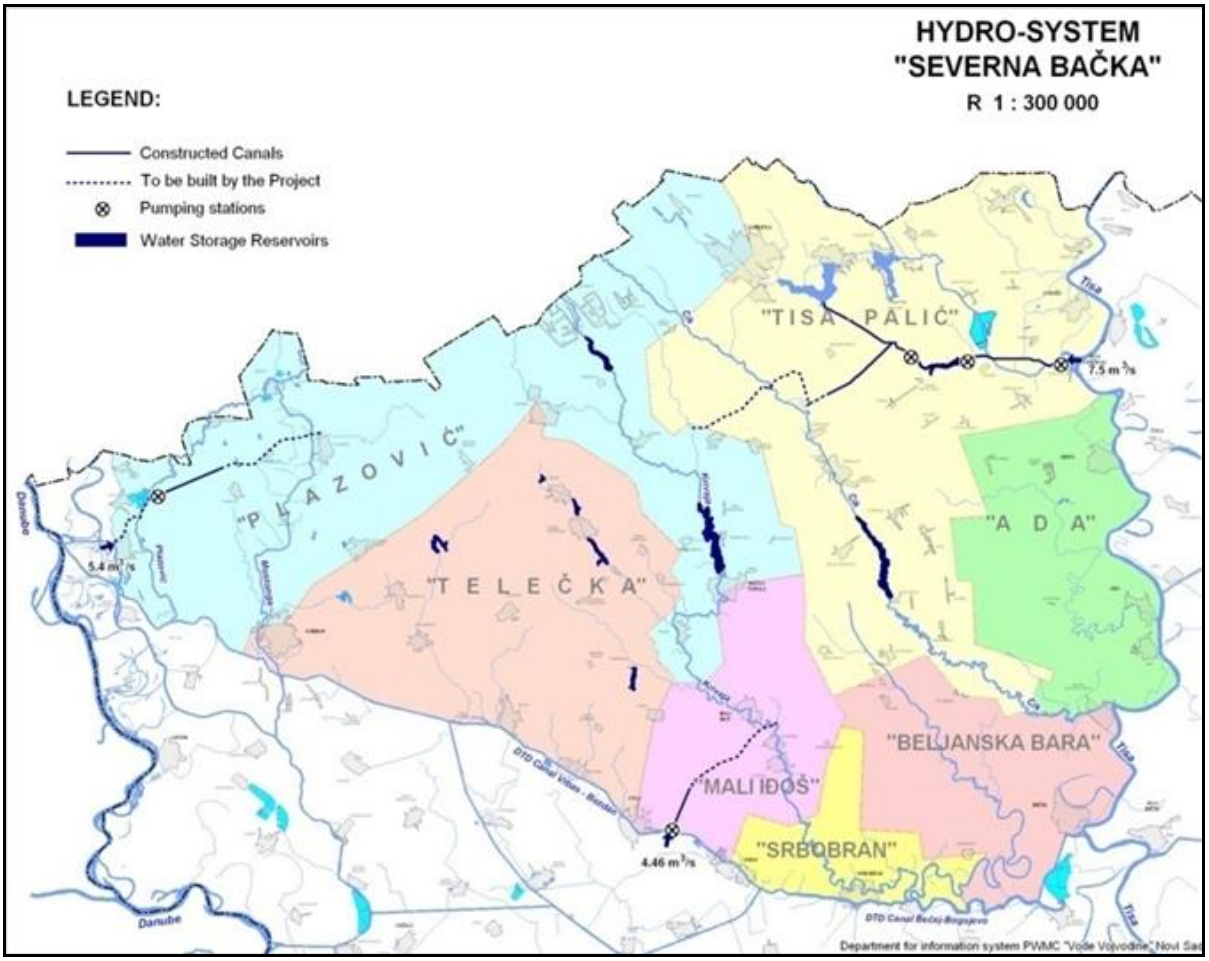


Figure 15. Map of the North Bačka (Severna Bačka) Hydrosystem

Operation and maintenance of the sub-systems is contracted out to Regional Water Companies, as described in the brief on Governance. There are currently eight companies managing these 12 subsystems.

Irrigation canals

Table 6 shows the length of canals in each system and sub-system that may be used for irrigation, together with the planned area of land to be irrigated and the area that is currently operational:

Table 6. Irrigation under Vojvodina regional hydrosystems

System Sub-system	Irrigated area		Canal length			
	Planned	**Operational**	**Main canals**	**Secondary canals**	**= Total**	**of which, dual function**
Banat	102,200 ha	12,270 ha	139 km	43 km	**184 km**	170 km
Kikinda	30,000 ha	3,316 ha	31 km	10 km	**41 km**	41 km
Nadela	29,200 ha	2,435 ha	50 km	4 km	**54 km**	42 km
Nova Crnja-Žitište	19,800 ha	5,719 ha	34 km	18 km	**52 km**	52 km
Novi Kneževac	23,200 ha	800 ha	24 km	11 km	**37 km**	36 km
Severna Bačka	152,000 ha	14,125 ha	98 km	42 km	**119 km**	69 km
Ada	15,500 ha	4,086 ha	23 km	9 km	**32 km**	32 km
Beljanska bara	15,500 ha	4,567 ha	24 km	16 km	**41 km**	37 km
Mali Iđoš	15,500 ha	2,444 ha	15 km	0 km	**11 km**	0 km
Plazović	38,000 ha	0 ha	6 km		**6 km**	
Srbobran	10,900 ha	0 ha				
Telečka	21,600 ha	0 ha				
Tisa - Palić	35,000 ha	3,028 ha	29 km	16 km	**29 km**	
Total	**254,200 ha**	**26,395 ha**	**237 km**	**85 km**	**303 km**	**240 km**

Source: Vode Vojvodine; data supplied 2020

The total area planned for irrigation is 254,000 ha, of which just over 26,000 ha (10 %) is currently operational.

Water is conveyed through just over 300 km of canals, three-quarters of which are main canals. In almost all cases, irrigation water must be pumped into the canals, using 17 main pump stations. The only exceptions will be gravity feed into the Plazović irrigation system (no land currently irrigated) and the Telečka irrigation system (under construction).

Some 240 km of these canals (80 % of the total canal length) are dual-purpose canals, used for drainage in winter and irrigation in summer.

Dual-purpose systems

Table 7 shows the area of land irrigated from dual-purpose canals:

Table 7. Dual-purpose canals in Vojvodina

Source & system	Irrigated area	Share of total
Surface	**9,329 ha**	**100%**
River	**2,875 ha**	**31%**
Begej	2,075 ha	22%
Tisa	800 ha	9%
System	**6,454 ha**	**69%**
Hs DTD	6,454 ha	69%
Total	**9,329 ha**	**100%**

Source: Vode Vojvodine; data supplied 2020

This shows just over 9,000 ha irrigated from dual-purpose canals, with 70 % of this area sourcing its water from the DTD system and 30 % drawing directly from rivers Tisa and Begej rivers. All water is supplied by pumping.

Irrigation: Water users

Table 8 gives a breakdown of the 103 registered users of irrigation water from Vode Vojvodine:

Table 8. Irrigation users, Vode Vojvodine

User type	No. users	Command area	Area irrigated in 2020		
			Area	Share	Av.
Company	6	53,976 ha	43,525 ha	88%	573 ha
Cooperative	14	7,433 ha	5,381 ha	11%	384 ha
Individual farmer	7	311 ha	281 ha	0.6%	40 ha
Institution	4	201 ha	131 ha	0.3%	33 ha
Total	**103**	**61,921 ha**	**49,318 ha**	100%	488 ha

Source: Vode Vojvodine; data supplied 2020

These users have a total command area of almost 62,000 ha, of which 49,000 ha was irrigated this year.

Ninety two of the users are companies or cooperatives. These have an average irrigated area of 540 ha and account for 99 % of the total area irrigated.

Only seven private farmers receive irrigation water from Vode Vojvodine, irrigating an average of 40 ha each.

The institutions are a research institute, an agricultural extension station, an agricultural high school and a state forestry company.

Irrigation: water sources

Table 9 shows the different sources of irrigation water:

Table 9. Irrigation water sources, Vode Vojvodine

Water source	Command area	Irrigated area	
Ground	**703 ha**	**599 ha**	**1%**
Surface	**61,218 ha**	**48,719 ha**	**99%**
Reservoir	3,983 ha	3,312 ha	7%
River	5,382 ha	3,795 ha	8%
System:	51,853 ha	41,612 ha	84%
Drainage canal	*3,172 ha*	*1,871 ha*	*4%*
Hs DTD	*42,546 ha*	*34,004 ha*	*69%*
Regional	*6,135 ha*	*5,737 ha*	*12%*
Total	**61,921 ha**	**49,318 ha**	**100%**

Source: Vode Vojvodine; data supplied 2020

Only 1 % of the water came from boreholes, with 99 % from surface water sources. The registered boreholes are all used by institutions, companies or cooperatives, not by individual farmers.

Of this surface water, 15 % was abstracted directly from rivers or reservoirs, with 85 % drawn from canal systems ultimately managed by Vode Vojvodine.

The DTD Hydrosystem accounted for almost 70 % of the total area irrigated, showing the importance of this multi-purpose navigation/drainage/irrigation system. From an economic perspective, a key point here is that this system was already built and would need to be managed, maintained and operated even if it were not used for irrigation, though the capital and recurrent costs of irrigation pump stations are specific to irrigation.

Informal water use

These data only relate to registered users and do not include unlicensed private boreholes and surface water intakes. The total area irrigated from official sources in 2020 was 49,000 ha, which may be compared with the total of 75,000 ha reported for Vojvodina in the 2018 Farm Structures survey. This suggests that around 26,000 ha, or 35 % of the total area, was irrigated from informal sources.

Irrigation technologies: Source to field

The process of irrigation can be split into the following steps:

SOURCE

1. ***Abstraction*** from the source, which is normally a river, reservoir or aquifer
2. ***Conveyance*** to the command area, if it is not immediately adjacent to the source
3. ***Distribution*** to farms and fields in the command area

FIELD

4. ***Application*** to the crop

CROP

There may also be steps of ***Storage*** at any point from source to field.

This chapter looks at the main ways that irrigation water is brought to the field in Serbia. It discusses the main technologies used, the number of farms and area of land applying each approach, the strengths and weaknesses of current technologies, and ways in which the irrigation process could be made more efficient and hence more profitable.

The chapter after this takes a similar approach to analysing the different ways in which water is applied to the crop.

4 SWOT ANALYSIS OF WATER SOURCES

This section looks at the Strengths, Weaknesses, Opportunities and Threats of the different water sources, as identified in the 2018 Farm Structures Survey and as discussed in section 3 on public irrigation systems. Basic data on water sources were presented in Table 2 above; the three tables below present additional information to inform this SWOT analysis.

Table 10 shows the total number of irrigating farms and the areas irrigated by water source, together with a breakdown of the irrigated area by farm size. Farm sizes are shown as the following groups:

- Small: <= 5 ha
- Medium: 5-50 ha
- Large: > 50 ha

Table 11 breaks these irrigated areas down by type of crop grown. Crops are placed into two value groups:

- HVCs: High-value crops (vegetables, potatoes, fruit, grapes)
- LVCs: Low-value crops (cereals, pulses, industrial crops, forage crops)

This table also shows an estimate of the total value of irrigated output from each water source.

Table 12 shows the interaction between water source and application method, which is discussed in more detail in the next section on *Surface water on* the holding

Surface water on the holding is the main source of irrigation water for:

- 10 % of irrigating farms
- 10 % of irrigated area
- 8 % of irrigated high-value crops
- 9 % of irrigated output value
- Average area irrigated = 0.6 ha per farm using this source

Most of the irrigation systems using his source are very small-scale irrigation and may be as simple as a tractor-driven pump lifting from a local stream, as well as fixed pumps supplying drip irrigation systems. The water source may range from a small stream to the Sava or Danube. Some of the farms in this category will use large, professionally-designed systems, which may originally have been installed for an agro-kombinat.

The relatively small coverage from this source reflects the fact that most farms do not happen to have a convenient river running through or beside their holding. It is unclear whether this category would also include irrigation from a drainage canal next to the holding.

The key features of this source are that, like groundwater on the holding, it is managed and financed by one farm, for one farm, and is often unlicensed.

This is the third most common source of irrigation water in Serbia, used by 10 % of irrigating farms and supplying 10 % of irrigated land.

It is most commonly used by small farms, supplying 13 % of their irrigated area, and its importance decreases with farm size, to 10 % of irrigated land on medium-sized holdings and 7 % on large farms.

It is not a major water source for irrigated high-value crops, supplying only 8 % of their area, but is slightly more important for low-value crops, at 12 % of area. Just over half (54 %) of the water from this source is used to irrigate low-value crops.

Surface water on the holding supports an estimated 9 % of irrigated output, with an annual value of almost € 80 million.

In terms of application technology, the dominant system is sprinkler irrigation (68 % of area), with 15 % of area using surface irrigation and 17 % using drip. This is consistent with the picture of tractor-driven pumps feeding portable sprinkler systems.

In summary, surface water on the holding is the third most important source of irrigation water in Serbia, whether measured by number of farms, irrigated area or output value, though it does not exceed 10 % of the total by any of these measures. It more common on smaller farms and for low-value crops, and is most usually applied by sprinkler.

This source has many features in common with groundwater on the holding, so in the following SWOT analysis, points that are essentially the same as the previous section are shown in grey.

Strengths

- ***Institutionally simple:*** There is no institution, as one farm has full responsibility.
- ***Financially sustainable:*** Farms pay the full cost and reap the full benefits of this kind of irrigation, and so are highly likely to maintain the system as long as it continues to be profitable.
- ***Low cost conveyance:*** By definition, the water source is on or adjacent to the farm, so conveyance pipelines are short.
- ***Flexible and low cost:*** The simple systems using tractor-driven pumps and portable sprinklers are relatively cheap and can be moved to where they are needed (though the permanent drip systems using this source will be more expensive and inflexible).
- ***High uptake:*** Farmers will only invest in these systems if they intend to use them, so there will be very little land that is equipped with an irrigation network but not actually irrigated.

Weaknesses

- ***Risk of over-abstraction:*** There is little control over water abstracted from small rivers and streams, so there is a risk that farmers will over-abstract in the summer, possibly harming the river environment or depriving downstream users.
- ***Medium pumping cost and greenhouse gas emissions:*** These systems will typically lift water only a short distance, keeping the pumping cost down, but the widespread use of petrol and diesel motors is relatively inefficient and has an environmental cost from the emission of greenhouse gases.
- ***Unreliability:*** For small water courses, the biggest risk is that the river will run dry in the height of summer, just as it is needed most.

- ***Geographically limited:*** The biggest limitation is that most farms do not have a river running through or beside their holding.

Opportunities

- ***Careful expansion:*** Most of Serbia's large rivers could support a substantial increase in water abstraction, making this a good option for farms that happen to be in the right place. Care will be needed to ensure that intakes do not interfere with navigation and river flow, or harm the environment.
- ***Electrification:*** Bringing mains electricity to users of surface water will reduce costs, increase reliability and reduce greenhouse gas emissions.
- ***Better monitoring and management:*** Improvements in surface water monitoring, modelling and permitting will help ensure that expansion only takes place where it is safe, and provide a clearer legal basis for connection to the electricity grid. Improved systems may also be used to reduce over-exploitation of rivers that are under seasonal pressure.
- ***Increased irrigation efficiency:*** Improvements in application techniques (see section 4.2) could reduce the amount of water withdrawn from rivers with limited summer flow.
- ***Increased storage:*** New reservoirs could greatly increase the summer flow of small rivers, though at a cost. These investments are most likely to be cost-effective when they will support high-value crop production, or bring additional benefits such as flood control.

Threats

- ***Declining and more variable rainfall:*** In the long-term, climate change may reduce the average flow of the small and medium-sized rivers on which many of these farms depend, though this effect is expected to be small over the period covered by this strategy. An earlier impact of climate change may be more frequent summer droughts, so there may be more years in which this source cannot satisfy demand.
- ***Inefficient regulation:*** Regulators are generally more concerned about preserving scarce drinking water than protecting small watercourses, but there is still a risk that insensitive enforcement could unnecessarily harm agricultural production.

4.1 Groundwater on the holding

Groundwater on the holding is the main source of irrigation water for:

- 51 % of irrigating farms
- 45 % of irrigated area
- 60 % of irrigated high-value crops
- 55 % of irrigated output value
- Average area irrigated = 0.5 ha per farm using this source

This source is where the farm gets its water from a private well or borehole, usually unlicensed. The farm has complete responsibility for the whole irrigation process from abstraction to application.

This is the most common source of irrigation water in Serbia, used by 51 % of irrigating farms and supplying 42 % of irrigated land.

It is the main water source for small and medium farms, supplying 57-61 % of their irrigated area, but supports only 17 % of the irrigated area on large farms.

This is also the main water source for irrigated high-value crops, supplying 60 % of the area under these crops. Overall, 74 % of the groundwater-irrigated area is under high-value crops.

Groundwater supports an estimated 55 % of irrigated output, with an annual value of just under € 500 million.

In terms of application technology, sprinkler irrigation (48 % of area) is slightly more common than drip (42 % of area); groundwater is rarely applied by surface irrigation (10 % of area).

In summary, groundwater on the holding is the most important source of irrigation water in Serbia, whether measured by number of farms, irrigated area or output value. It is particularly important for small and medium-sized farms and for high-value crops, and is usually applied by sprinkler or drip.

Strengths

- ***Institutionally simple***: There is no institution, as one farm has full responsibility.
- ***Financially sustainable***: Farms pay the full cost and reap the full benefits of this kind of irrigation, and so are highly likely to maintain the system as long as it continues to be profitable.
- ***Low cost conveyance***: Boreholes are normally located in or close to the fields to be irrigated, so conveyance pipelines are short.
- ***High uptake***: Farmers will only invest in boreholes if they intend to use them, so there will be very little land that is equipped with an irrigation network but not actually irrigated.
- ***Substantial share of high-value crops***: Since farmers have to meet the full costs of this kind of irrigation (less any grant support for purchase of irrigation equipment), they usually make this investment only when they intend to grow high-value crops.

Weaknesses

- ***Risk of over-abstraction***: With most boreholes being unregulated, there is a risk that farmers will over-abstract groundwater and lower the water level in the aquifer. This may occur when they tap into deep aquifers that recharge only slowly (and typically contain high-quality water suitable for drinking) or where they use shallower aquifers but abstraction is greater than recharge.
- ***High pumping cost***: Many well pumps are not connected to the electricity network and so rely on relatively expensive petrol or diesel motors, either to pump water directly or to generate electricity for submersible pumps. This is more of an issue where aquifers are deep.
- ***Greenhouse gas emissions***: Petrol and diesel motors also have an environmental cost from the emission of greenhouse gases. Electric pumps have lower impact, though with much of Serbia's electricity generated from lignite, their impact is still significant.
- ***Unreliability***: Petrol and diesel motors require more maintenance than electric pumps and are more prone to breakdowns. In remote areas, electricity connections may not be reliable.
- ***Geographically limited***: Not all farms have a suitable source of groundwater, so this option is only applicable in some cases.

Opportunities

- ***Careful expansion***: For aquifers where abstraction is less than recharge and there is no conflict with municipal water supplies, the area of land irrigated from groundwater can be expanded.
- ***Electrification***: Bringing mains electricity to users of boreholes will reduce costs, increase reliability and reduce greenhouse gas emissions.
- ***Better monitoring and management***: Improvements in groundwater monitoring, modelling and permitting will help ensure that expansion only takes place where it is safe, and provide a clearer legal basis for connection to the electricity grid. Improved systems may also be used to reduce over-exploitation of those aquifers that are under pressure.
- ***Increased irrigation efficiency***: Improvements in application techniques (see section 0 below) could reduce the amount of water withdrawn from vulnerable aquifers.

Threats

- ***Declining aquifers***: Over-abstraction in some cases is lowering water levels and so increasing the pumping cost for all groundwater users. Eventually some irrigation wells may run dry, threatening both irrigation and other users.
- ***Inefficient regulation***: Strict enforcement of current regulations, without improved knowledge and more efficient procedures, could close down a large proportion of Serbia's irrigated agriculture, at great economic cost.

4.2 Surface water on the holding

Surface water on the holding is the main source of irrigation water for:

- 10 % of irrigating farms
- 10 % of irrigated area
- 8 % of irrigated high-value crops
- 9 % of irrigated output value
- Average area irrigated = 0.6 ha per farm using this source

Most of the irrigation systems using his source are very small-scale irrigation and may be as simple as a tractor-driven pump lifting from a local stream, as well as fixed pumps supplying drip irrigation systems. The water source may range from a small stream to the Sava or Danube. Some of the farms in this category will use large, professionally-designed systems, which may originally have been installed for an agro-kombinat.

The relatively small coverage from this source reflects the fact that most farms do not happen to have a convenient river running through or beside their holding. It is unclear whether this category would also include irrigation from a drainage canal next to the holding.

The key features of this source are that, like groundwater on the holding, it is managed and financed by one farm, for one farm, and is often unlicensed.

This is the third most common source of irrigation water in Serbia, used by 10 % of irrigating farms and supplying 10 % of irrigated land.

It is most commonly used by small farms, supplying 13 % of their irrigated area, and its importance decreases with farm size, to 10 % of irrigated land on medium-sized holdings and 7 % on large farms.

It is not a major water source for irrigated high-value crops, supplying only 8 % of their area, but is slightly more important for low-value crops, at 12 % of area. Just over half (54 %) of the water from this source is used to irrigate low-value crops.

Surface water on the holding supports an estimated 9 % of irrigated output, with an annual value of almost € 80 million.

In terms of application technology, the dominant system is sprinkler irrigation (68 % of area), with 15 % of area using surface irrigation and 17 % using drip. This is consistent with the picture of tractor-driven pumps feeding portable sprinkler systems.

In summary, surface water on the holding is the third most important source of irrigation water in Serbia, whether measured by number of farms, irrigated area or output value, though it does not exceed 10 % of the total by any of these measures. It more common on smaller farms and for low-value crops, and is most usually applied by sprinkler.

This source has many features in common with groundwater on the holding, so in the following SWOT analysis, points that are essentially the same as the previous section are shown in grey.

Strengths

- ***Institutionally simple***: There is no institution, as one farm has full responsibility.
- ***Financially sustainable***: Farms pay the full cost and reap the full benefits of this kind of irrigation, and so are highly likely to maintain the system as long as it continues to be profitable.
- ***Low cost conveyance***: By definition, the water source is on or adjacent to the farm, so conveyance pipelines are short.
- ***Flexible and low cost***: The simple systems using tractor-driven pumps and portable sprinklers are relatively cheap and can be moved to where they are needed (though the permanent drip systems using this source will be more expensive and inflexible).
- ***High uptake***: Farmers will only invest in these systems if they intend to use them, so there will be very little land that is equipped with an irrigation network but not actually irrigated.

Weaknesses

- ***Risk of over-abstraction***: There is little control over water abstracted from small rivers and streams, so there is a risk that farmers will over-abstract in the summer, possibly harming the river environment or depriving downstream users.
- ***Medium pumping cost and greenhouse gas emissions***: These systems will typically lift water only a short distance, keeping the pumping cost down, but the widespread use of petrol and diesel motors is relatively inefficient and has an environmental cost from the emission of greenhouse gases.
- ***Unreliability***: For small water courses, the biggest risk is that the river will run dry in the height of summer, just as it is needed most.
- ***Geographically limited***: The biggest limitation is that most farms do not have a river running through or beside their holding.

Opportunities

- ***Careful expansion***: Most of Serbia's large rivers could support a substantial increase in water abstraction, making this a good option for farms that happen to be in the right place. Care will be needed to ensure that intakes do not interfere with navigation and river flow, or harm the environment.
- ***Electrification***: Bringing mains electricity to users of surface water will reduce costs, increase reliability and reduce greenhouse gas emissions.
- ***Better monitoring and management***: Improvements in surface water monitoring, modelling and permitting will help ensure that expansion only takes place where it is safe, and provide a clearer legal basis for connection to the electricity grid. Improved systems may also be used to reduce over-exploitation of rivers that are under seasonal pressure.
- ***Increased irrigation efficiency***: Improvements in application techniques (see section 0 below) could reduce the amount of water withdrawn from rivers with limited summer flow.
- ***Increased storage***: New reservoirs could greatly increase the summer flow of small rivers, though at a cost. These investments are most likely to be cost-effective when they will support high-value crop production, or bring additional benefits such as flood control.

Threats

- ***Declining and more variable rainfall***: In the long-term, climate change may reduce the average flow of the small and medium-sized rivers on which many of these farms depend, though this effect is expected to be small over the period covered by this strategy. An earlier impact of climate change may be more frequent summer droughts, so there may be more years in which this source cannot satisfy demand.
- ***Inefficient regulation***: Regulators are generally more concerned about preserving scarce drinking water than protecting small watercourses, but there is still a risk that insensitive enforcement could unnecessarily harm agricultural production.

4.3 Surface water off the holding

Surface water off the holding is the main source of irrigation water for:

- 27 % of irrigating farms
- 39 % of irrigated area
- 24 % of irrigated high-value crops
- 28 % of irrigated output value
- Average area irrigated = 0.9 ha per farm using this source

This category covers any farm that brings water from a river or reservoir outside its boundary. Effectively it includes four very different cases:

- Individual irrigation systems run by and for a single farm, which are identical to those using surface water on the holding, except that they have had to negotiate a right-of-way and install a pipeline or small canal to bring water from a more distant source. Many of the ex-kombinat systems fall into this category, using their previous status and financial strength to establish the route and any necessary pump stations and pipelines.
- Irrigation from the drainage systems of the DTD hydrosystem and in Maćva, where Vode Vojvodina or Srbijavode and the local municipality are responsible for ensuring the water supply in the canal.

- Multi-user pressurised systems, such as that at Negotin and a number of new systems currently under design or construction.
- Canals constructed specifically for irrigation. Currently there is only one such canal functioning in Serbia, the new Mali Iđoš canal that is filled by pumping from the DTD system. However, a number of other canals are currently under consideration so it is useful to analyse this approach.

The average area irrigated from surface water off the holding is just 0.9 ha, showing that many farmers use this source to irrigate small areas, typically of fruits or vegetables. However, it also supplies some of the largest irrigation systems in the country, including over 400 large farms that irrigate an average of almost 100 ha each.

Surface water off the holding is the water source that is most likely to be licensed, regulated and billed to the user. This applies to most farms irrigating from the DTD and Maćva drainage canals, but only to a few large users in Central Serbia.

Institutionally, financially and economically, this is a complex group which includes both individual irrigation and public multi-user systems. A more detailed breakdown would be useful but cannot be obtained from the existing survey data.

This is the second most common source of irrigation water in Serbia, used by 27 % of irrigating farms and supplying 39 % of irrigated land.

It is most commonly used by large farms, supplying 71 % of their irrigated area, and supplies 22 % of the irrigated area on both small and medium-sized holdings.

This is the main water source for irrigation of low-value crops such as cereals and oilseeds, supplying 57 % of their total irrigated area. Almost two-thirds (65 %) of the water from this source is used to irrigate these low-value crops. However, this source is also used by some producers of high-value crops, supporting 24 % of the total area under irrigated fruits, vegetables and potatoes.

Surface water on the holding supports an estimated 28 % of irrigated output, with an annual value of just over € 250 million.

In terms of application technology, the systems reflect the focus on larger fields and arable crops, with surface and sprinkler irrigation being of almost equal importance (44-45 % of area). Only 11 % of water from this source is used for drip irrigation.

In summary, surface water off the holding is the second most important source of irrigation water in Serbia, whether measured by number of farms, irrigated area or output value. It more common on larger farms and for low-value crops, and is usually applied by surface or sprinkler irrigation.

SWOT analysis is complicated by the fact that irrigation from this source is highly varied, so each of the four sub-cases is discussed separately.

4.3.1 Irrigation of individual farms from surface water source off the holding

In most respects, this form of irrigation is identical to Surface water on the holding, as discussed above. Only significant differences are noted here.

Strengths

- ***More reliable water supply:*** In many cases, these systems have been built to take water from larger rivers with reliable summer flow and with less risk of harming other users or the environment.

Weaknesses

- ***Institutionally complex to establish:*** Whilst farmers may have a legal right to lay a pipeline across their neighbour's land, the legal, practical and social costs will often be prohibitive. However, once the system is in place, it is institutionally simple and financially sustainable.
- ***Geographically limited:*** If farmers are able to cross others' land to reach the river, then more land is potentially irrigable. Even so, most of Serbia's cultivated land does not lie within 1-2 km of a suitable river.
- ***Higher conveyance cost:*** Pipelines and pump stations are expensive, so this source will almost always cost more than surface water on the holding.

Opportunities

- ***Expansion:*** Facilitating individual farms' access to rivers could expand the irrigated area without requiring complex institutional systems or making any long-term commitment of public funds.
- ***Electrification:*** Development of individual irrigation systems along major rivers could be supported by the installation of electricity lines following the river.

Threats

- ***Some risk of declining and more variable rainfall:*** Whilst climate change will affect most rivers eventually, it is typically a less immediate constraint for the larger rivers which these systems tend to use.

4.3.2 Irrigation from dual-purpose drainage systems

This approach currently applies to the DTD and Maćva drainage systems, though there may be scope to apply it elsewhere. It is based on maintaining a constant water level in the drainage canals throughout the year, with the flow reversing during the irrigation season. In some cases this may involve pumping from the river back into the canal, as well as pumping to higher parts of the drained area.

Water is delivered to the field either through sub-surface pipe drains, or by pumping water up the short lift from the drainage canals and then applying it through the usual options of surface, sprinkler or drip irrigation.

Strengths

- ***Existing institutions and funding mechanisms:*** The two-tier institutional structure for drainage already exists, along with its funding mechanisms, and can be used for irrigation as well.
- ***Cost sharing:*** Maintenance of canals can be costly but most of the network is already being maintained for drainage. The extra costs of switching to two-way drainage arise from the need to construct some additional pump stations, electricity lines and control structures, plus the cost of pumping itself.
- ***Potentially high uptake:*** With the drainage network bringing water close to every field in the command area, the investment and operating costs to farmers should be relatively low

and so uptake may be expected to be high. This should be verified with Vode Vojvodina for those areas where two-way drainage has already been operating for some years.

- ***Reliable water supply:*** Most of the drained areas feed into the Sava or Danube, which offer a reliable, year-round water supply which is currently far from fully used.

Weaknesses

- ***Mainly low-value crops:*** The drained areas are mainly sown to low-value arable and fodder crops, so conversion to two-way drainage will only be viable where costs can be kept down.
- ***Some geographical limitations:*** This approach is possible only for those areas already equipped with drainage, but this area is quite large.

Opportunities

- ***Expansion:*** In principle, this approach could be expanded throughout most of the drained area, only excluding land that is considerably higher than the river into which it drains. The main deciding factors will be uptake and cost.
- ***Electrification:*** Where it is necessary to supply electricity to pump stations on the canal network, it may also be possible to bring electricity to irrigating farms at reasonable cost.

Threats

- ***Underfunding:*** Vode Vojvodine already faces difficulties in obtaining sufficient funds to maintain the drainage network properly, so it is not clear whether the additional costs of two-way drainage would be adequately covered.

4.3.3 Irrigation from multi-user pressurised systems

There are very few multi-users pressurised systems yet in function, but quite a number in various stages of design. Most rely on pumping, either directly from the river to the command area or up to a header reservoir. In hilly areas it is sometimes possible to create the reservoir above the area to be irrigated, so that the pressure is provided by gravity.

Most of the systems currently under discussion would be relatively small and would probably to be run by the local municipality or some organisation of water users, rather than by Srbijavode or Vode Vojvodine.

The following SWOT analysis does not address the issue of water availability, as it is different in every case.

Strengths

- ***Irrigation on demand:*** Pressurised systems offer maximum flexibility to farmers, particularly where a header reservoir supplies a constant pressure. This translates into good service and higher yields.
- ***Suitable for high-value crops:*** These systems offer a reliable source of pressurised water that is highly suitable for drip irrigation of fruits, nuts, greenhouses etc., though not all farmers in the command area will chose to grow such crops.

- ***Water-efficient:*** Closed systems have low conveyance losses and the provision of water under pressure encourages farmers to use sprinklers or drip, rather than surface irrigation.
- ***No on-farm pumping needed:*** With water delivered to the farm under pressure, farmers do not have the cost and reliability issues of on-farm pumping, and do not need an electricity supply (other than for powering the movement of large centre-pivot or linear irrigation machines).

Weaknesses

- ***Institutionally complex:*** New institutions will usually be needed to run these systems. Tariffs will need to be agreed and funding mechanisms established.
- ***Expensive:*** The capital cost of pressurised systems is typically several thousand euros per hectare and is increased where new reservoirs have to be built. In addition to the ongoing costs of pumping, skilled staff are needed to maintain and operate these complex systems.
- ***Uptake often low:*** Experience in the region suggests that not all farmers offered access to new pressurised systems will chose to use them, and that many who do will continue to grow low-value crops.
- ***Geographically specific:*** These systems are typically designed to take advantage of local conditions, such as a large river adjacent to fertile land, or a river that can easily be dammed to create a storage reservoir.

Opportunities

- ***Multi-purpose reservoirs:*** Where reservoirs are anyway required for flood control or other purposes, the additional costs of developing an irrigation system may be reasonable.
- ***Replacement of groundwater:*** If an area already has a strong focus on high-value crops, but irrigation is currently based on declining aquifers, new multi-user pressurised systems may be cost-effective.

Threats

- ***Financial unsustainability:*** Unless there is high uptake and a substantial share of high-value crops, it will usually be impossible to set a tariff high enough to recoup the capital cost. In some cases the scheme may not be able to cover operating and maintenance costs without subsidy, bringing a serious risk of gradual dilapidation where public funding is insufficient.
- ***Weak management:*** Most of the local organisations expected to run these systems do not have previous experience of irrigation or may not yet exist. These systems are technically, organisationally and socially complex, with considerable scope for mistakes.

4.3.4 Irrigation from purpose-built canals

As noted earlier, the only purpose-built irrigation canal currently functioning in Serbia is the new Mali Iđoš canal that is filled by pumping from the DTD system. Other potential canals under discussion would take water from the Sava or Danube to irrigate land some distance away.

Strengths

- ***Reliable water supply:*** All of the proposed systems target areas with a plentiful source of river water.
- ***Long reach:*** Canals offer almost the only affordable way to bring irrigation water to fertile land that is not close to a river or over a suitable aquifer.
- ***Long lifetime:*** Canals require regular maintenance, and unlined earth canals in particular deteriorate quickly if not cleaned regularly. However, if properly maintained, canals can last indefinitely. Britain has a network of functional navigation canals dating back to the 18th century, plus one working canal that was built by the Romans around AD 120. Hence canals are almost the only element of today's irrigation systems that are likely to still be in place to help Serbia adapt to the climate change expected in the second half of this century.

Weaknesses

- ***Expensive and complex to build:*** Capital costs include not just the canal itself, but the lengthy and complex process of procuring a continuous strip of land and of handling all of the roads, cables and pipes that cross its route.
- ***Complex to manage:*** Sophisticated management is needed to maintain constant water levels in large canal networks, particularly if they aim to provide farmers with water on demand.
- ***Institutionally complex:*** The Mali Iđoš canal supplies a small number of large farms, who have been left to make their own arrangements for getting water from the canal to the crop. Where canals are used to supply many small farms, they typically require two tiers of organisation, with one body managing the main canals and pump stations, and smaller local bodies handling distribution to farmers and collection of fees.
- ***Typically used for low-value crops:*** Most canal systems aim to supply large areas of land, on which only a proportion of farmers will use the water for high-value crops.

Opportunities

- ***Expansion:*** There is a large area of land that could potentially be irrigated from new canals, though it is less clear how much of this would be economic.

Threats

- ***Financial unsustainability:*** There is very little chance that tariffs will ever recoup the full capital costs of a new canal system, so it would have to be funded by government and would represent a significant subsidy to the farmers fortunate enough to have land in the command area. Many canal systems around the world struggle to cover their costs and so it is common to see a "dilapidation-rehabilitation cycle" whereby inadequate funding leads to poor maintenance and a gradual decline in infrastructure and service, until a project is found to rehabilitate the canal and start the cycle again.

4.4 Vodovod

The public water-supply network is the main source of irrigation water for:

- 7 % of irrigating farms
- 2 % of irrigated area
- 3 % of irrigated high-value crops
- 3 % of irrigated output value
- Average area irrigated = 0.2 ha per farm using this source

This source refers to water from the public water supply network, which in some cases has been deliberately over-sized to let it support irrigation as well as domestic demand. The average area irrigated is only 0.2 ha and 70 % of the irrigated area is under high-value crops, suggesting that this source is used mainly for nurseries, greenhouses and small areas of fruits and vegetables, whose output value can cover the relatively high water price. Outside agriculture, this source is widely used to irrigate parks, gardens, golf courses and sports grounds. It is the only source of irrigation water that is fully regulated and billed.

This source of irrigation is perhaps surprisingly common, used by 7 % of all irrigating farms, but most of these farms are small and so it covers only 2 % of all irrigated land.

Water is most usually applied by sprinkler (71 % of area) and then by drip (26 %). Only 3 % of area from this source uses surface irrigation, probably where a farmer just places a running hose on the ground and moves it periodically.

This source supports an estimated 3 % of irrigated output value, around € 25 million annually assuming typical cropping mix and yields.However, with this likely to be a major source for greenhouses and nurseries, the true output value could be considerably higher.

In summary, the public water supply network is the main source of irrigation water for a small but significant number of farms, often used to irrigate the highest-value crops by sprinkler or drip.

Strengths

- ***Institutions exist:*** Local water supply companies exist throughout the country and already have the necessary mechanisms to measure and bill for water, whatever it is used for.
- ***Financially sustainable:*** Governments ensure that water companies have sufficient funding to maintain the domestic water supply.
- ***Cost sharing:*** Irrigation from this source normally uses networks that already exist and have been paid for, though a dual-purpose system for an area with many irrigating farmers would require bigger pipes and higher cost.
- ***No uptake issue:*** All farm households use the water supply network, if it reaches them, so no money is wasted in laying irrigation pipes to farms that in the end do not use it.
- ***Substantial share of high-value crops:*** This expensive water source is normally used just for high-value crops, including ornamentals and amenity areas.
- ***Reliability:*** Provides a reliable source of pressurised, high-quality water.
- ***Wide coverage:*** Most of the country is supplied by water supply networks, apart from outlying homes in rural areas, giving farmers almost anywhere the possibility of setting up a greenhouse or nursery using this source.

Weaknesses

- ***Competes for a high-value resource:*** Drinking water must be of high quality and is normally sourced from deeper groundwater or well-protected reservoirs. Some of these sources are already under pressure and so must prioritise domestic use over irrigation.
- ***Network pressure:*** If a lot of farmers use this approach from a network that was not designed for it, it may cause drops in pressure and bring problems for other, higher-priority water users.
- ***Expensive:*** The extensive networks and high requirements for water quality and reliability make this an expensive source of irrigation water, only viable for high-value crops.

Opportunities

- ***Dual-purpose systems:*** In some cases, it may be more cost-effective to install and maintain one dual-purpose network than to have one drinking water system and a separate pressurised irrigation network.

Threats

- ***Increasing pressure on limited supplies:*** Several of Serbia's aquifers are already declining and climate change may further reduce recharge. Meanwhile, changing patterns of urbanisation and industrial development are increasing demand in some areas. Expansion of tap-water and dual-purpose irrigation should only be encouraged where supplies are expected to be adequate for many years to come.

4.5 Other sources

The main source of irrigation water was described as "Other" for:

- 5 % of irrigating farms
- 5 % of irrigated area
- 5 % of irrigated high-value crops
- 5 % of irrigated output value
- Average area irrigated = 0.6 ha per farm using this source

No information is available from the census or survey as to what these "Other" sources were, though it should include groundwater off the holding (which will provide the source for much of the area under the "Resavska celina" irrigation system to be financed by EBRD). It is also possible that some of the farmers ticking this box used multiple irrigation sources and could not easily identify one as their main source.

"Other sources" are used by 5 % of all irrigating farms, covering 4-5 % of irrigated area across all size categories.

This irrigated land is used almost equally for high-value and low-value crops, with around half the area irrigated by sprinkler and a quarter each by surface irrigation and drip.

It is estimated to support 5 % of the total value of irrigated output, worth over € 40 million per year.

In summary, "Other sources" account for around 5 % of total irrigation by every measure, with a broad mixture of crops and application technologies.

Without further information on this water source, no SWOT analysis is possible.

Irrigation technologies. Irrigating farms were asked whether they used surface irrigation, sprinkler irrigation or drip irrigation, and could indicate more than one method. Total areas irrigated using each method were estimated by apportioning the areas that used multiple methods[14].

Table 10. Irrigation by source & farm size

Water source	All irrigating farms				Land share by farm size		
	Number		Irrigated area		Small	Medium	Large
Groundwater on holding	135,000	*51%*	71,000 ha	*45%*	57%	61%	17%
Surface water on holding	27,000	*10%*	16,000 ha	*10%*	13%	10%	7%
Surface water off holding	71,000	*27%*	62,000 ha	*39%*	22%	22%	71%
Vodovod	18,000	*7%*	4,000 ha	*2%*	4%	3%	0%
Other	12,000	*5%*	7,000 ha	*5%*	5%	4%	4%
Total	**263,000**	***100%***	**160,000 ha**	***100%***	**100%**	**100%**	**100%**

Source: RZS: 2018 Farm Structures Survey

Table 11. Irrigation by source & crop type

Water source	Land share by crop type				Estimated value of irrigated output	
	HVCs		LVCs			
Groundwater on holding	53,000 ha	*60%*	18,000 ha	*26%*	€ 494 m	*55%*
Surface water on holding	7,000 ha	*8%*	8,000 ha	*12%*	€ 78 m	*9%*
Surface water off holding	22,000 ha	*24%*	40,000 ha	*57%*	€ 253 m	*28%*
Vodovod	3,000 ha	*3%*	1,000 ha	*2%*	€ 25 m	*3%*
Other	4,000 ha	*5%*	3,000 ha	*4%*	€ 43 m	*5%*
Total	**89,000 ha**	***100%***	**71,000 ha**	***100%***	**€ 892 m**	***100%***

Source: RZS: 2018 Farm Structures Survey

Table 12. Irrigation by source × method

[14] Where farms used both sprinkler and drip irrigation, but not surface irrigation, their irrigated area was split between sprinkler and drip in proportion to the known areas using just one of these two methods.

Where farms used surface irrigation in addition to sprinkler and/or drip, their irrigated area was split between surface, sprinkler and drip in proportion to the known areas using any one of these methods.

The calculation was carried out on the total areas using each water source.

Source	Application method (estimated areas)							
	Surface		Sprinkler		Drip		All methods	
Groundwater on holding	7,100 ha	*10%*	34,300 ha	*48%*	29,800 ha	*42%*	**71,200 ha**	***100%***
Surface water on holding	2,300 ha	*15%*	10,700 ha	*68%*	2,600 ha	*17%*	**15,600 ha**	***100%***
Surface water off holding	27,000 ha	*44%*	28,000 ha	*45%*	6,900 ha	*11%*	**61,900 ha**	***100%***
Vodovod	100 ha	*3%*	2,600 ha	*71%*	1,000 ha	*26%*	**3,700 ha**	***100%***
Other	1,900 ha	*27%*	3,400 ha	*47%*	1,900 ha	*26%*	**7,200 ha**	***100%***
Total	**38,500 ha**	***24%***	**79,000 ha**	***49%***	**42,100 ha**	***26%***	**159,600 ha**	***100%***

Source: RZS: 2018 Farm Structures Survey

5 IRRIGATION TECHNOLOGIES

Предности, слабости, могућности и претње различитих облика површинског наводњавања, наводњавања прскалицама и кап по кап процењене су у засебном кратком прегледу под насловом „Технологија наводњавања у Србији“.

6 EXPECTED IMPACTS OF CLIMATE CHANGE

As shown in the previous section, the economic costs and benefits of irrigation depend on four factors::

- Rainfed yields and margins
- Irrigated yields and margins
- Quantity of irrigation water needed
- Cost of supplying that water

It is also essential to know whether or not the desired quantity of water will be available.

Climate change is likely to affect all of these factors, with consequent implications for the costs and benefits of irrigation. Table 13 presents a qualitative summary of the changes projected to occur over the period 2020-2050 and of the effects (where known) that these are likely to have on five representative crops:

Table 13. Expected impact of climate change from 2020 to 2050

Factor	Overall effect
Temperature	Average temperatures increasing by 0.9-1.2 °C; higher maximum & minimum temperatures; more frequent, longer & hotter heat waves; shorter & warmer cold periods.
Evapotranspiration	Increasing by 39-63 mm/year, mainly due to the increase in temperature.
Precipitation	No big change in average annual precipitation over this period, with no significant changes in seasonality or rainfall intensity,
Groundwater availability	The combination of higher ET but constant precipitation will increase the water deficit and reduce the total amount percolating down to aquifers. The effect is likely to be small over this period, so the supply from alluvial aquifers will remain plentiful but aquifers which are already under pressure will become more stressed.
Surface water availability	Runoff to surface water will tend to decrease due to higher evapotranspiration. Flow in the major rivers will continue to be ample for the current irrigated area and some considerable expansion.

	Flow in small rivers and streams may become limiting in the height of summer.				
Reference crop:	**Winter wheat**	**Grain maize**	**Potatoes**	**Tomatoes**	**Apples**
Other crops with similar behaviour	All winter cereals	Most spring-sown industrial crops (soya, sunflower, oilseed rape, sugar beet)	Spring-sown root vegetables, e.g. carrots, onions	Fruiting vegetables, e.g. peppers, cucumbers	All pome fruit, stone fruit & perennial berry fruit
Rainfed yield	Small increase	Small decrease	Decrease	Decrease	Decrease
Irrigated yield	Unchanged (no heat effect)	Possible heat & disease effects?	Possible heat & disease effects?	Possible heat & disease effects?	Possible heat & disease effects? Possible effect of fewer cold days?
Захтеви за наводњавање	Unchanged	Increase	Increase	Increase	Increase

Further analysis of climate change will be provided in the Programme document and its annexes, and in the accompanying “Irrigation Atlas of Serbia”.

7 CONCLUSIONS AND KEY ISSUES

The main purpose of this brief is to establish the factual background, rather than to identify issues and make recommendations. Development of the strategy should take careful account of the following points, several of which are commonly misunderstood or overlooked::

- Wide variation in farm sizes
- Fact that even small farms are mostly commercial
- Fact that most production of all crop groups is rainfed
- Dominant role of individual irrigation
- Major role of groundwater
- Key differences between large and small farms in what they grow and how they irrigate